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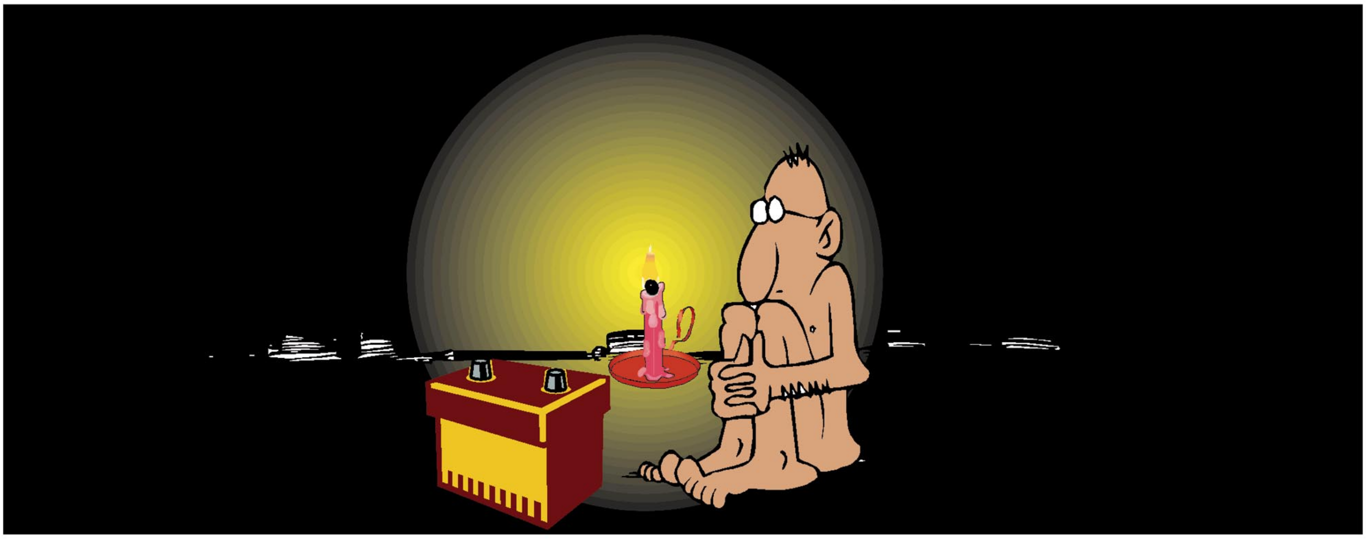

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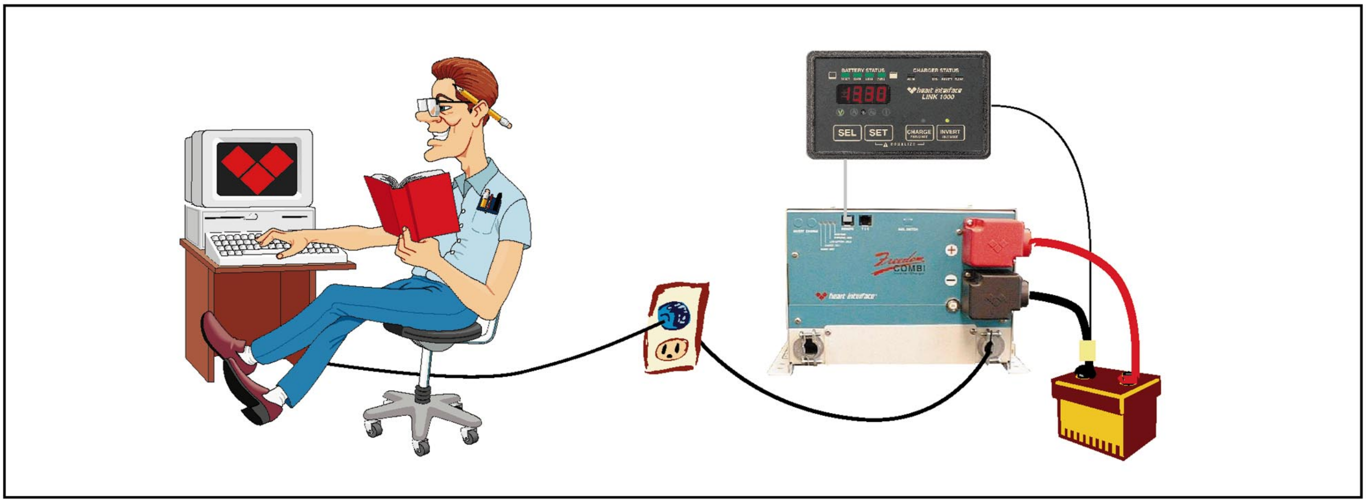

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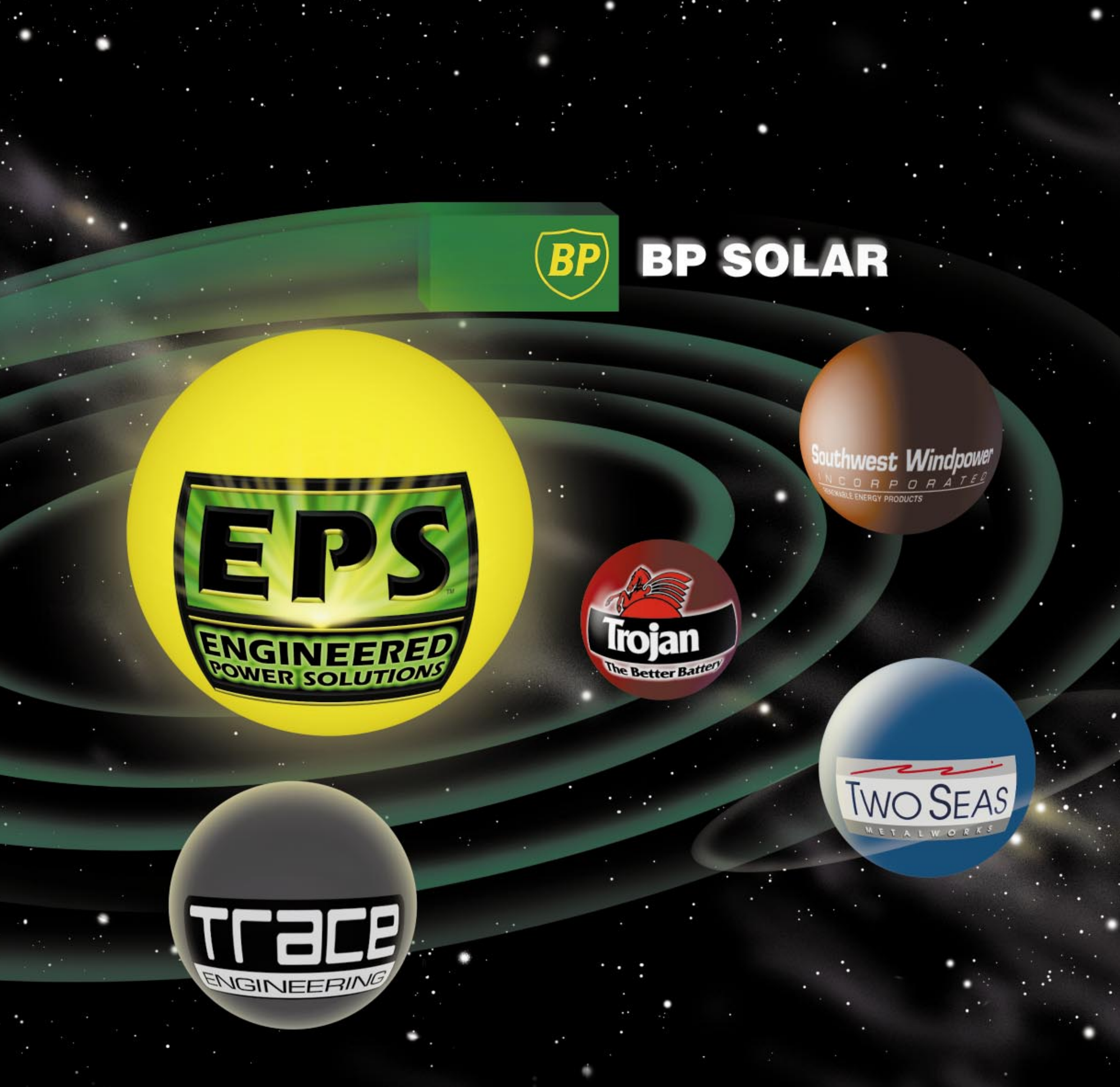
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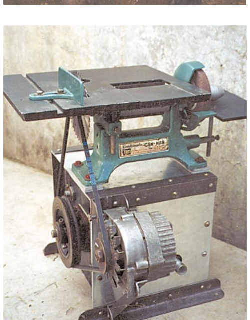

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The Season Is Here

April marked the beginning of the season for energy fairs and all those installation and maintenance projects we've put off over the winter.

Arcata's 8th annual Renewable Energy Fair kicked off the fair season with a fantastic exposition. The fair's pride and joy was its new 1.2 KW PV array powering the main stage, in spite of the fog rolling in mid-afternoon. There was also a 350 watt system that powered the secondary performance stage. (At least there wasn't an earthquake or rain, as has happened in the past.)

Bart Orlando did up some popcorn in his huge parabolic cooker. Pedal-powered smoothies were slurped by the masses. Kudos go to solar bozos Sean Armstrong and Steve Sakala of the Campus Center for Appropriate Technology at Humbold State University. They weren't clowning around when they organized one of the best REFs ever.

New to the fair was a long row of pre-owned EVs, all courtesy of one of the nation's first used EV dealerships, Arcata ElectriCar. Another special treat was a veggie oil-powered, 2 ton truck from a local organic farm. The owner picks up fryer grease at local restaurants when he brings his produce to town, then takes the oil back to the farm for processing into diesel fuel.

Summer is here, so it's time to raise the tilt of your modules and do your annual greasing of the wind genny. It's also time to finalize your plans for attending the other fairs around the country. Please join the *Home Power* crew at the Midwest Renewable Energy Fair in Amherst, Wisconsin, June 18–20; at SolWest in John Day, Oregon, July 24–25; and at the Southwest Renewable Energy Fair in Flagstaff, AZ, September 18–19, 1999.

–Michael Welch, for the *Home Power* crew

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Dave Wilmeth
Myna Wilson
Ian Woofenden
Nikolai Alexanderovich Zarick

"Think about it…"

"I'm in charge of my own electric system. I can't imagine ever living on the grid again."

—Lou Ann Washington, page 32

Mobile SOLAR

Eric Kindseth
& Nicole Burbridge


Eric and Nicole are solar-mobile with their photovoltaic system on wheels.

We were both in our mid-twenties, and hadn't gathered the necessary funds to purchase our dream property. We wanted a home of our own, but didn't like the obvious choices: trailer, tent, or yurt. Instead, we decided on a movable two-part home. Wanting a full scale alternative energy system, we constructed a mobile companion power center called the SolarWagon!

We are the caretakers of a beautiful piece of property in rural northeastern California, nestled in a mountain valley at 4,700 feet (1,433 m). Summers are dry and hot while winters are typical of the Sierra, with snowstorms interspersed with weeks of crisp sunshine. The grid lies four miles (6.4 km) distant, so making our own power is both a necessity and a priority.

Our systems have evolved out of unique and changing needs. Initially, a used car battery and a PV module I assembled from individual cells provided more light and music than we could use. However, we soon yearned for more power!

Still Looking for Our Own Place
After searching in vain for years for the property of our dreams, we decided to build our movable micro dwelling and major power system anyway! The year before beginning the project, we recycled a turn of the century 3,000 square foot (279 m^2) home. It provided all of the lumber for the construction (and more!) but only after pulling gazillions of nails. But that's a story in itself...

One of the main criteria in our house design was the ability to move it. It proved to be very challenging to incorporate efficiency, durability, aesthetics, and mobility into our design. From our experience living on a sailboat, we knew how to build our 500 square foot (46 m^2) home to be as space efficient as possible. Making it mobile was new territory for us.

After a lot of research and design, we decided to build the house so that it would separate into two modules for transportation on a heavy duty trailer. The modules are narrow enough for legal travel on our local highways. When assembled, they resemble a conventional home. Nicole has made me promise that when we find our own land, moving them will be feasible.

Mobile? Yes!
About this time, our seven-year-old golf cart batteries were in need of replacement. We were able to buy twelve surplus AT&T Lineage 2000 lead-acid batteries for our new system. The round, industrial, 1680 AH, 2 volt cells weigh in at a whopping 340 pounds (154 kg) each! Needing a facility for the new batteries played

into our decision to build the new mobile power center. By designing and building the SolarWagon to be movable, we are able to have a safe, secure, and cleanly installed power system that can be transported to a new site when necessary.

Hardly a double-wide, the modular house splits in half for relocation.

SolarWagon Construction

The "foundation" for the SolarWagon is a securely welded frame, hitch, and axle assembly. The rest of the structure is conventionally framed and is insulated to R-19.

The SolarWagon consists of two distinct compartments—the vented battery area and the component center. We wanted to keep the structure compact, so the batteries are accessed through the hinged roof. The electrical components are accessible through two small doors. After building the low-pitched roof to withstand four to six feet (1.2-1.8 m) of snow pack, we discovered that it took all of our strength and more to open it, even when the roof was dry. The thought of trying to open the roof with thousands of additional pounds of wet snow on it was sobering.

The solution was to employ a motorized actuator liberated from its former insipid service operating a television satellite dish. Although intended to operate on 36 VDC, the 52 inch (132 cm) actuator effortlessly opens the 250 pound (113 kg) "lid" completely in less than two minutes with the flip of a three-way switch. What a relief!

Batteries

When we built the SolarWagon, we made sure that the battery section was completely isolated from the electrical components, after discovering the truth behind the old adage "sparks and hydrogen don't mix."

I learned this important lesson while equalizing half of the battery bank. I was adjusting a battery cable and I created a small spark. Even though the charging was taking place outside in open air (pre-SolarWagon), the spark ignited the hydrogen gas that was present, causing one battery to explode. Luckily, I escaped with only my pride injured. We now have a policy of wearing protective clothing and eye and face protection whenever working around batteries. In retrospect, we would also encourage you not to work on your battery bank while it is charging to the gassing point.

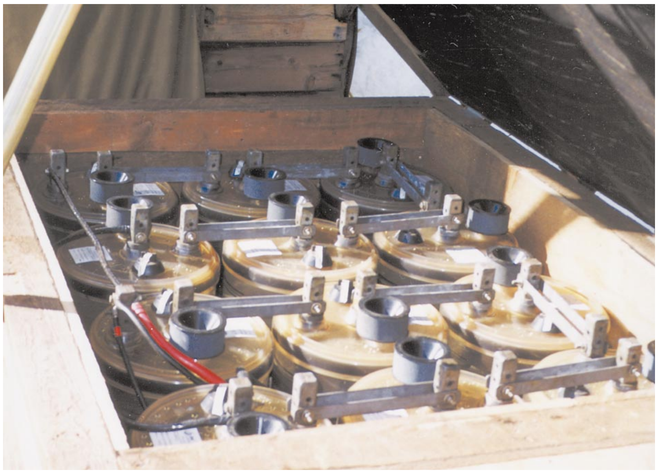
The round 2 volt cells are divided into two strings of six series wired batteries, connected in parallel. They store 3,360 amp-hours at 12 volts, so it should be a while before we outgrow this large battery! The copper bars that were included with the batteries make clean durable interconnects. As long as we don't try any more spontaneous welding experiments, the batteries should require minimal maintenance.

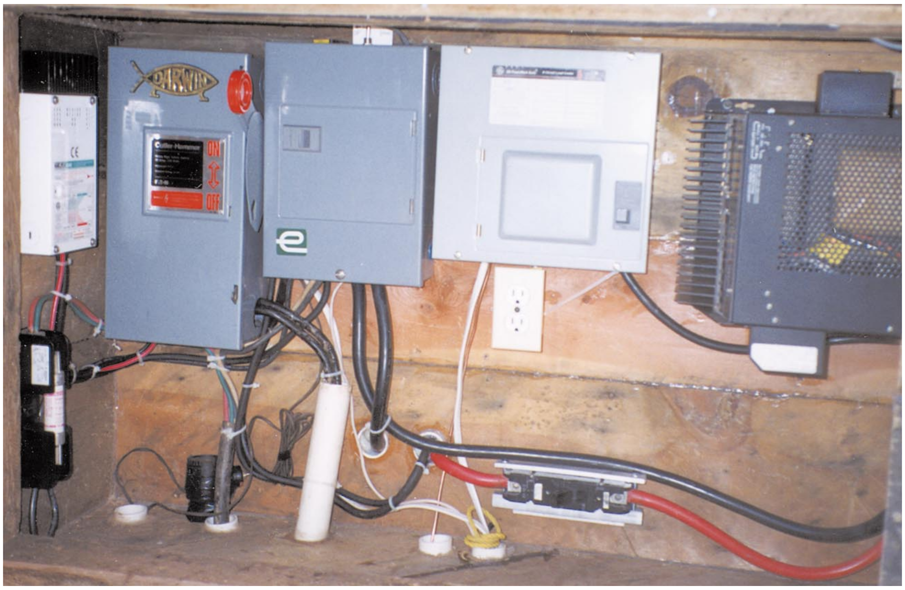
Nerve Center

On the east side of the SolarWagon, the electrical power center is accessed through two insulated doors. This nerve center is completely isolated from the battery compartment. The ventilation ducts are positioned to promote cross-flow within the compartment.

The 2/0 (67 mm^2) cable from the array enters a fused disconnect switch, and then continues to the Trace C-40 charge controller. We wired the disconnect to isolate

Twelve Lineage 2000 lead-acid cells provide 3360 amp-hours of storage at 12 volts.





From left: Trace C-40 charge controller, PV and controller disconnect breakers, DC load panel, AC load panel, and Trace U2512 inverter.

the C-40 from the solar panels and the battery positive when in the *off* position. Adjacent to the switch is a DC load center with breakers for the DC circuits.

Squeezing the 500 amp shunt for the state-of-charge (SOC) meter into the load center is a neat and clean installation detail. We use a TriMetric meter to monitor our system loads and have it remotely located in the house. In addition to voltage, amperage, and amp-hours, the meter has several user adjustable parameters.

Nicole and Eric's System Costs

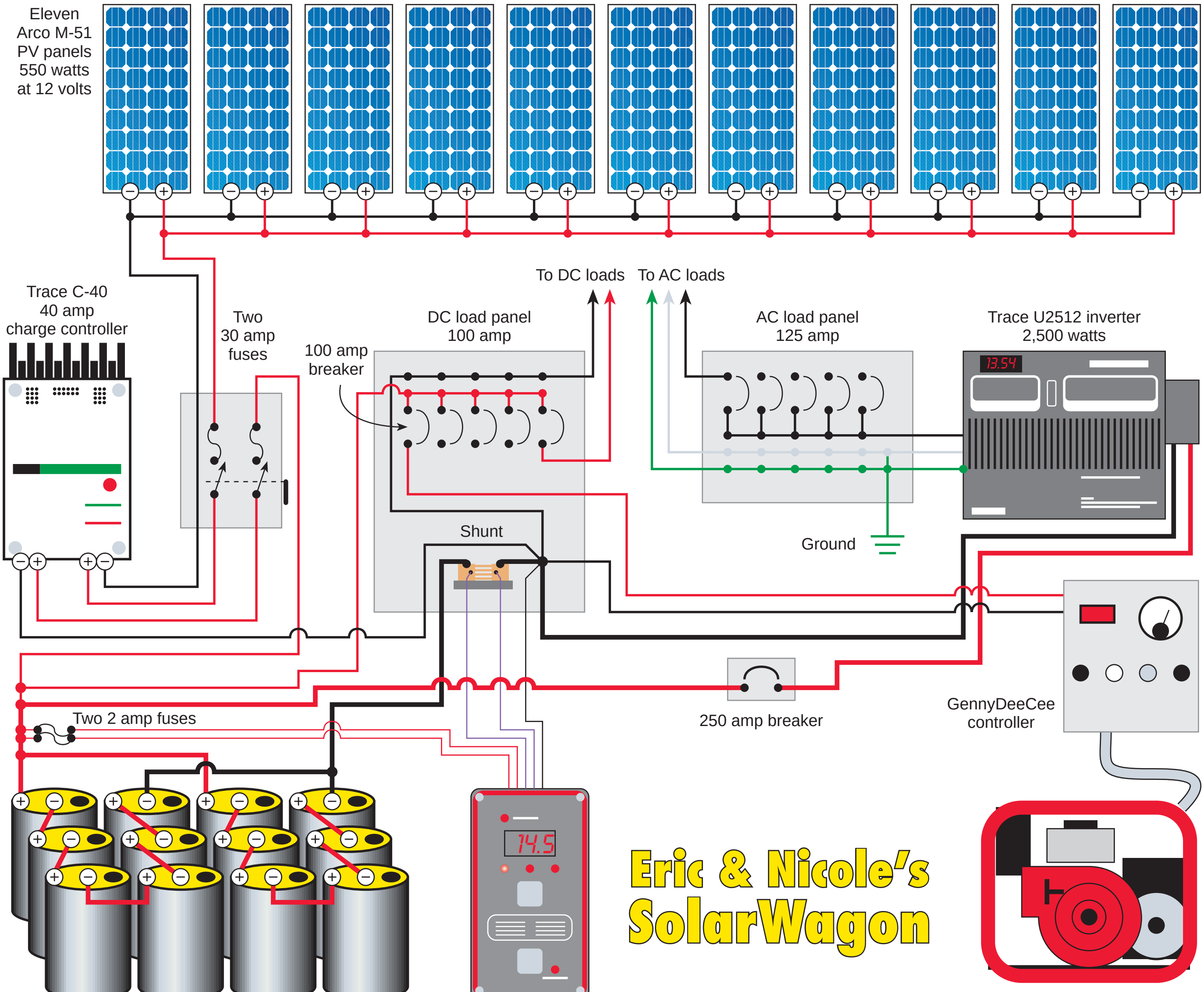
Component	*Cost*	*Percent*
11 Surplus Arco M-51 modules	$1,650	27.6%
100 amp 12 V GennyDeeCee	$1,385	23.2%
Twelve 2 V, 1,680 AH batteries	$1,200	20.1%
Trace 2512 inverter	$950	15.9%
Used Wattsun tracker	$250	4.2%
Tri-Meteric battery monitor	$169	2.8%
#2/0 and #4/0 copper wire	$150	2.5%
Trace C-40 charge controller	$100	1.7%
30 amp fused disconnect	$72	1.2%
100 amp DC distribution panel	$30	0.5%
125 amp AC panel	$25	0.4%
SolarWagon materials	$0	0.0%
Misc. salvaged components	$0	0.0%
Array rack	$0	0.0%
Total	$5,981	

Inverter

We are very happy with the Trace U2512 inverter. During construction, it fed all the loads we put on it, including a 1.5 HP compressor, table saw, and 2 worm-drive saws! A 250 amp DC circuit breaker/disconnect joins the positive side of the Trace inverter to the positive side of the battery. We wired a remotely operated on/off switch for the Trace in the house. Occasionally we turn it off when it causes radio interference on the AM band. A 120 VAC load center is mounted adjacent to the inverter. The breakers control the various AC loads in the house and shop.

To fit all the components into such a compact space, we shuffled cardboard cutouts throughout the compartment until we had the placement just right. This technique is a great way to plan for the most efficient installation. Having learned the importance of planning ahead for expansion, we left room for more expensive toys!

The SolarWagon all opened up. Notice the R-19 insulation throughout.



Solar Panels

The solar charging is provided by eleven Arco photovoltaic panels arranged on two racks. One rack is homebuilt; the other is a Wattsun single axis tracker. The array produces 25 amps in full sun, rendering a charging rate of C/134. Heavy 2/0 (67 mm^2) cable carries the current 30 feet (9 m) to the SolarWagon. Our location provides ample sun for much of the year, but during winter and early spring we are affected by periods of minimal sun. For this reason, and to supply extra power for the house building project, we needed a generator.

GennyDeeCee

Having a large enough inverter supplanted the need for a 110 VAC generator. We couldn't justify the common and hopelessly inefficient practice of using an AC generator to charge a DC battery through a converter/charger. What we really needed was a DC generator to charge our battery pack directly. We found the perfect generator for our needs—the 100 amp 12 VDC GennyDeeCee.

We purchased the generator in 1997 from the manufacturer, Feather River Solar Electric. The engineering and workmanship on the unit are impressive. Like our Trace inverter, the GennyDeeCee is overbuilt and conservatively rated. It's also uniquely flexible—it can be operated at any charging output. By varying the rpm and the field controller setting, we can dial in the exact charge rate we need. It allows us to use battery power whenever we want, and do the charging at the most convenient time.

During the building projects we ran the GennyDeeCee often, accumulating nearly 300 operating hours. We didn't need to run the generator to operate a specific tool or appliance like you would do with an AC generator if you didn't have a large inverter. We enjoyed the ability to run the GennyDeeCee even when we weren't home to hear it! We felt comfortable leaving the GennyDeeCee running when we weren't home because of its simplicity and redundant safety features, which include automatic timer shutdown and low oil pressure shutdown.

Left: The SolarWagon closes up tightly against the weather.

Right: GennyDeeCee makes up for times of no sun.

We are able to get the full 100 amps out of the generator at our 4,700 foot (1,433 m) elevation. However, for our power needs and best fuel economy, 85 amps is the ideal setting. Aside from changing the oil at the recommended 100 hour intervals, the generator has been maintenance-free.

Having Our Cake And Eating It Too!

Based on our experiences living off-grid for the past ten years, we were able to build up our new power system with confidence and get the performance we desired. Setting up a large-scale residential photovoltaic system can be a demanding endeavor on any site, and incorporating mobility was indeed a challenging engineering exercise.

Although probably not for everyone, having a moveable system allows us the flexibility of having big-time renewable energy now while we patiently look for our own dream property. Who ever said that you can't "put the cart before the horse?" We say, "If the cart is solar-powered, go for it!" As long as the sun continues to shine, we will be blessed with a clean, renewable, and sensible power source for a long time to come.

Access

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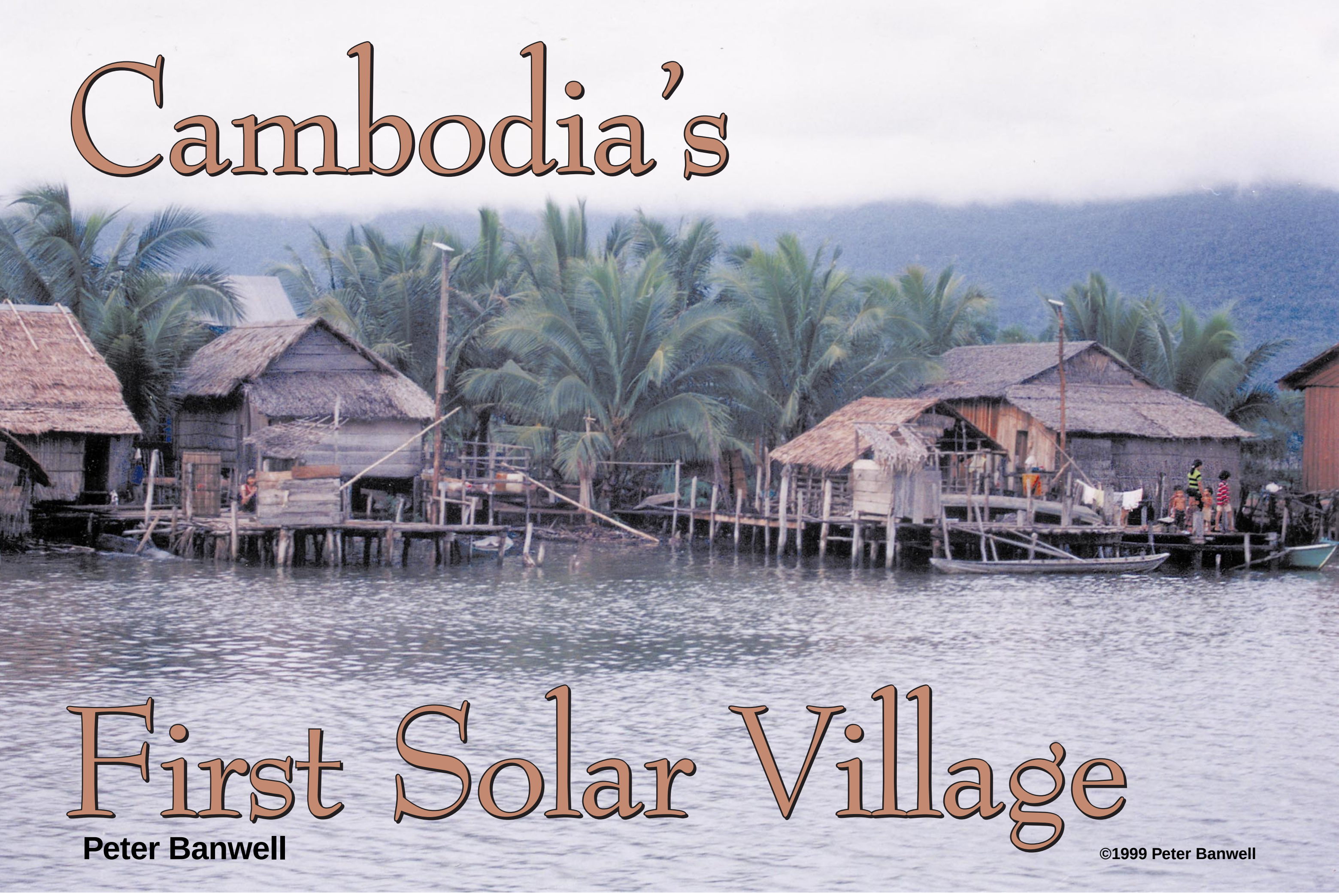
Cambodia's First Solar Village

Peter Banwell



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Samaki village fishermen's houses with small PV modules on poles.

Cambodia is small tropical Southeast Asian country of about 10 million people. The country is largely rural, with the majority of the population living in the provinces. Due to the rural population and lack of government funds for electrification, approximately 85 percent of the country is not electrified.

The parts of the country that do have electricity have only intermittent service. Electric power service for households generally consists of small generators, private power vendors who own large generators and sell power to houses, and battery charging stations for small 12 volt systems.

In 1997, my wife was offered a job with the Asia Foundation to run the Women's Economic and Legal Rights Program in Phnom Penh. I was able to take a year off from my energy efficiency job in Washington, DC, and went to Cambodia with the goal of starting a small PV business in Phnom Penh.

Starting a PV Business

Since we expected to stay for just one year, I began by trying to find a partner who could continue the business after we left. After a long search, I found Mr. Ford Thai, a local businessman with extensive business experience and the ability to speak six regional languages as well as English and French. Ford is a local legend. He's a Khmer (Cambodian) of Chinese descent who drives an American speedboat on the Mekong and takes his pet monkeys with him while installing PV systems. He is a colorful and delightful man, and it was a pleasure to work with him from the very beginning.

Our first task was to determine which solar products would succeed in Cambodia. We chose small PV lighting kits for use in the millions of countryside homes without electricity. We found that it was necessary to use Asian components. They were our only practical choice, given the cost of importing from the U.S. or Europe, and the price sensitivity of the Cambodian market.

The kits consisted of a solar module, a charge controller, a 12 volt light, and a battery. During our first few months, we installed a solar electric computer

system in a rural office and a lighting system for a rural health clinic. As we were growing, we registered our business with the government under the name Khmer Solar.

Government Connection
In pursuit of potential projects, I met with the Director of the Energy Department for the Cambodian government, Dr. Sat Samy. He was in the process of specifying and selecting solar equipment for a village solar project, and became interested in our solar lighting kits. After some tests of the kit at his house, many discussions, and comparison of our systems with others, we were awarded the contract to install 38 PV lighting systems.

The Project
The project plan was to bring solar lighting kits to Samaki, a small fishing and rice farming village near the Kampong Som and the Gulf of Thailand. The village was approximately 5 km (3 miles) from the nearest large town. The houses in the village were elevated on stilts, had one to two rooms, and were built in traditional Cambodian style, with bamboo framing supporting a palm frond roof.

As their only source of lighting, villagers were using small kerosene wick lamps, which were dim, smoky, and dangerous. The villagers did not own batteries since they were unable to transport them back and forth to a larger town for recharging. Solar electric lighting kits were the first source of electricity in these homes. The kits were designed to provide one to three hours of light per night, depending on the season.

Selecting & Testing the PVs
We looked north to China to supply the modules for the lighting kits. China has a thriving domestic market for PV and it was our closest economical choice for small modules. Through a regional renewables advocacy group, we found Yunnan Semiconductor, a Chinese manufacturer offering good quality modules. Their features include 36 single crystal cells, aluminum frames, ETA backing, imported low iron glass, and a 20 year warranty.

Our tests revealed that the modules were not producing their rated current and they were also not properly marked with current and voltage data on the back. We suspected that we had been shipped the wrong size of modules. Upon further discussions with the factory, we learned that the Chinese have a rather odd system for classifying modules. They have three 12 watt modules: 12A, B, and C, with C having the lowest output. We were sent 12B modules, which have the engineering specifications of 11 watt modules. Although the Chinese never agreed with our logic, or we with theirs, in the end we were issued a refund equal to one watt per module.

Installing a solar panel on a pole.

Choosing Charge Controllers
The lighting kit was to have one small charge controller to protect the battery from overcharge and overdischarge. We tested two types: the Morningstar 6.0 and the Steca Solsum 5.6. Many of the features were similar. Both had protection from reverse polarity, were suitable for tropical environments, had two year warranties (the Steca warranty was extended for this project), met quality standards set by the World Bank for PV projects, had low voltage disconnect, and had PWM charging.

After all of these features were examined and weighed, we found that the Steca had one significant technical advantage over the Morningstar: an LED that changes color with battery voltage, then flashes a cutoff warning at low voltage. In contrast, the Morningstar will disconnect loads without warning. With the small systems we were planning to install, an unexpected load cutoff could have left villagers in the dark for over a week while the battery recharged from a small PV panel. In the end, this feature and the much lower price for the Steca convinced the Energy Department. Since making the selection, we have found that Steca's customer service and distributor support is excellent.

Selecting Batteries
Since deep cycle batteries were unavailable in Cambodia, our choice was to either import deep cycle batteries at $200 each or use standard car batteries at

Khmer Solar technician, Toch Sovanna, prepares charge controllers. Ford Thai, president of Khmer Solar, watches.

$23. The economics strongly favored using car batteries. We recommended a 32 AH car battery, which we expect to last 2-4 years, depending on maintenance.

Car batteries are widely used in Cambodia for rural electrification in homes such as the ones in Samaki village. Tens of thousands of people in the countryside bring their 50-100 AH batteries in to a charging station once a week, and have learned that fully discharging the battery comes at the cost of battery life. With this infrastructure in place in the larger towns near the village, we decided that car batteries were a reasonable choice. Automotive batteries are not ideal, but they are cheap, and with proper maintenance they can last a long time. The village chief is responsible for battery maintenance, and each homeowner was given a small bottle of battery water to keep near their system.

Using the Steca

The charge controller is an essential element in maintaining the health of the car batteries. For the charge controller to be effective, we needed to teach the homeowners what the LED indicator lights meant. We did this in two ways. First we had a training session for all homeowners, and then we distributed booklets written in Khmer explaining what the color changes meant. The goal here was to get the homeowners accustomed to "reading" their charge controller, and keeping their battery as full as possible. We designed the systems for a typical daily battery depth of discharge of ten percent.

The settings on the charge controller are as follows: green is 12.7 V, yellow is 12.3 V, red is 11.8 V, flashing occurs below 11.8 V, and cutoff happens at 11.1 V. Reconnect voltage is 12.6 V, and the charge controllers have temperature sensors to compensate for high temperatures.

Testing and Selecting Lights

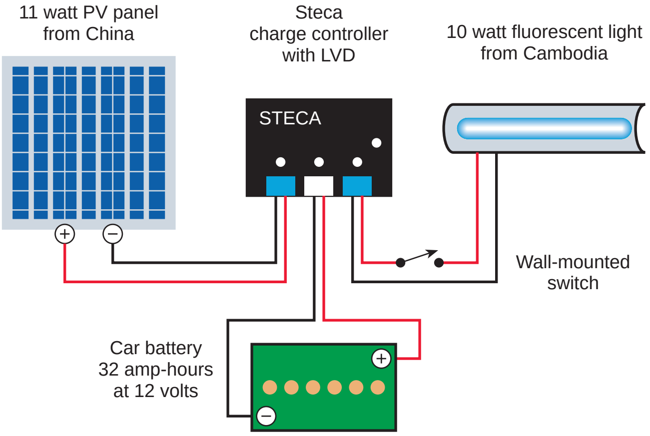
The homes in the village were small, and the project goal was to bring light to just one of the small rooms. There were several lights available to us for comparison: a reasonable quality import at a good price, a moderate quality, low price fixture made locally, and a screw-based compact fluorescent from China.

The Energy Department was not interested in the screw based fluorescent, since the villagers could not easily and economically replace it. After comparing the lights, they chose the locally made fixture, a 10 watt straight tube with a reflective backing. While we encouraged them to step up in quality to an imported fixture, we recognized that locally made fixtures were used all over Cambodia and would be very easy to repair or replace.

The Installation

On the day before the installation, we assembled in the garage under the Khmer Solar office. The crew of seven was made up of Khmer Solar technicians and employees from the Energy Department. The crew had a good mix of experience. Some of us knew the solar side well, and others were electricians or electrical

Samaki Village System



engineers who were highly skilled with tools and wiring. The imported items had made it through customs, and we had all of our equipment for the project. On the bare floor we laid out all the modules, charge controllers, mounting racks, sub-boards, lights, wires, screws, bolts, and tools.

At sunrise the next day we left Phnom Penh by car and truck, winding our way out of the city against the incoming swarm of motorcycle commuters. After a few hours on a good road, we turned onto a dirt track that ran between the rice fields. Fishermen worked their nets in the clay-lined canals next to the road. Soon the group crossed an old metal bridge leading to our destination—Samaki village.

Ford Thai and Ly Che Chen on their way to the next two houses.

Samaki is a small rice farming and fishing village on the Prek Kampong Smach River, near the coast. It has a population of approximately 200. We were led to the village chief, who was in a large courtyard area under his elevated home. This area served as our staging ground where we set up all of our equipment and worked out of the sun and rain.

When we started working on the installation, the seven of us broke up into teams of two or three, each with our own equipment and a full set of tools. The village had fishermen's houses near the river, and rice farmers' houses far off in the rice fields. Our job was to install systems in all of the houses, so we expected lots of walking.

Wiring & Installing the Modules

Although I can list a number of quality features of the Yunnan modules, the junction box is not on that list. The box was a tiny thing, leaving no room for any type of fasteners. To make the electrical connection, we had to solder the wires directly to the plus and minus tabs in the junction boxes. Although soldering is time consuming, it did give us a high quality connection.

Outside of the cities, Cambodians commonly use traditional palm fronds for their roofs. The fronds are replaced every couple of years, so it was necessary to install the modules on poles instead of roof mounting them. We used wooden poles standing next to—but higher than—the roof, facing south at an eleven degree angle.

By the end of the first day, we had installed most of the poles, and two complete systems. After finishing our work, we drove to the beach, walked through the palms, and swam under the stars. The only light was from the moon, which slowly rose over the gulf of Thailand. The other beach inhabitants were large fruit bats that floated gracefully past us through the tropical night.

Installing Charge Controllers

When we started early the next morning, we began with the charge controllers, batteries, and lights. We prepared the charge controllers by mounting them to small wooden sub-boards, which were spray painted either bright orange or dramatic silver. We used large screws to affix them to the wooden framing in the house, at eye level, where homeowners could easily see the LED voltage indicator lights.

Then we ran into a problem. The Steca charge controller works best with single strand wire since its junction holes are close together. But because we were using multi-strand wire, single wires easily strayed from their narrow space and shorted the circuit, causing

PV Lighting Systems

Component	*Cost*	*Percent*
11 watt modules	$91	45.5%
Steca Solsum 5.6	$35	17.5%
Shipping, insurance, customs	$35	17.5%
32 AH car battery	$23	11.5%
10 watt fluorescent light	$8	4.0%
Iron mounting rack	$5	2.5%
Wiring, screws, etc.	$3	1.5%
Total	$200	

sparks, blown fuses, and furrowed brows. The solution was to prepare the wires beforehand at the chief's house, before they were installed in the houses. We trimmed the lose wires and treated them with solder. The solder bonded the wires into a single strand and the wires then slid into the connection holes easily.

Lights in the Darkness

We spent our third day finishing up the wiring on the charge controllers and lights, and our work proceeded without difficulties. It took three days to install the 38 systems. As we packed our equipment late on the last evening, a powerful wind began to blow—monsoon season was beginning. We were on a fishing pier a short distance from town, where we stayed for the sunset. As the tropical night quickly fell around us, the individual homes began to light up one by one, breaking out of the darkness for the first time.

We went back to visit the project several months after we completed the installation, arriving in the evening. As we walked through the village, we could see people in their houses sitting in small circles under their lights. They were reading, eating their evening meals, and talking. People reported that their systems were working very well, and although we don't have hard numbers to report yet, it appeared that they had learned to live within the energy budget of the small systems.

When our visit was over, we drove out and crossed several miles of rice fields before reaching the main road. Looking back before we turned towards Phnom Penh, we could see Samaki village, a small cluster of lights shining brightly against the dark backdrop of the mountains.

Access

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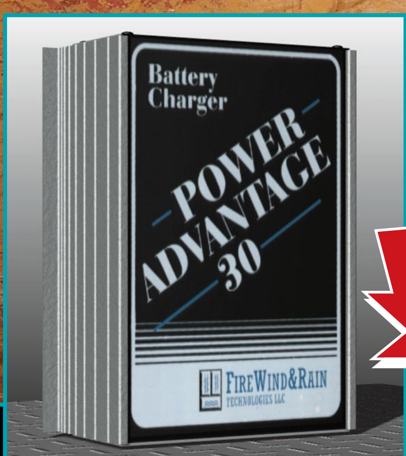

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Handyman's Special!

Mick Sagrillo

Lou Ann and Kelvin's wind/PV island in the sky.

In January of 1998, Lou Ann and Kelvin Washington were in the market for a new home, away from their hectic jobs in Denver. They found their piece of heaven high on a hilltop in South Park, Colorado. But their new dream home came with some problems, including a power system that was not the best introduction to renewable energy.

The house is 2,600 square feet (242 m^2), passive solar, and super-insulated, with a gorgeous view of the surrounding valley. They were told that the house had an "off-grid" electrical system. Being from the city, they had no idea what that meant. Nor could anyone vouch for its reliability.

Eric Westerhoff of Innovative Energy, the PV dealer from nearby Breckenridge, was contacted by the realtor to inspect the electrical system. What Eric found was that nightmare known as "the handyman's special!"

A Bit of History

The power system for the house was initially installed back in the mid-1980s, but evolved through the years. When we arrived on the scene, it consisted of twenty Kyocera 50 watt PV panels mounted on the roof. The PVs were series-paralleled, configured in five arrays with four panels in each array. Three of the arrays were regulated by one Trace C-30 charge controller, and the other two arrays passed through a second C-30. Maximum output of the 24 volt PV system was 35 amps.

The batteries and some of the controls were replaced in 1988. The new 24 volt battery bank consisted of twelve Trojan L-16s, series-paralleled for 1,400 amp-hours of capacity. Backup power was originally supplied by an 8.5 KW Onan LP (propane) generator through two Todd 75 amp battery chargers. Three 2,500 watt Heart Interface inverters supplied AC power to the house.

When the property changed hands in 1992, the new owners ran a small jewelry shop out of the house. It was during this time that the system fell into disarray. In order to meet production, the owners had to max out the system on numerous occasions, which eventually damaged the battery bank. The system was well used, but obviously with little preventive maintenance. Entropy set in, and system output declined. The owners depended on the Onan genset more and more.

Upon inspection, Eric found that the L-16s were more or less dead after only five years of service. During the day when the sun was shining, battery voltage climbed to 28 volts. When the sun set, however, the system voltage quickly fell to 19 volts. As a result, the inverters

shut down due to low battery voltage at night, and power had to be supplied to the house by the LP generator. Eric characterized the installation as "basically a direct drive system. You've got solar lights during the day, but LP lights when you most need them." Just prior to our arrival, the worn out Onan was replaced with a Generac 5,500 watt gasoline generator.

Superfund Site?

Eric remembers first approaching the battery/inverter/controller room and being overpowered by the smell of battery fumes. There was obviously something wrong. Among other things, Eric discovered that the Trace C-30s were operating continuously in the equalize mode. This resulted in the batteries merrily boiling away on bright sunny days.

Needless to say, the battery room was a toxic waste site. Battery acid had boiled over onto the concrete floor, etching canyons into the cement. Battery acid wicked up one wall of the room, dissolving the drywall in the process. The battery box hardware had begun to vaporize from the acid fumes. The previous owner had covered the spills with various layers of indoor-outdoor carpeting. As the carpeting decayed in the acid, bits of rubber and tuft were tracked away by visitors. Fortunately, most of the acid had been neutralized by the dissolving concrete.

Eric's inspection report to the realtor indicated that not only did the batteries need replacing, but the battery room also needed a complete overhaul. Once they closed on the house, Lou Ann and Kelvin bought new batteries from Eric. They also requested a general tune-up of the RE system.

Adding Wind

Eric had noticed that it was rather windy up on the hill, and suggested to the proud new owners that they might want to consider installing a wind turbine. He pointed out that the siding on the west side of the house had been caulked to reduce wind infiltration. Eric explained that adding wind to the PV system would increase the system's reliability. It would also reduce the amount of propane and generator time required to keep the batteries charged up. This sparked an interest in Lou Ann, and she asked Eric for a quote.

At this point, Eric knew he was getting in pretty deep. Since he'd never installed a wind turbine before, he contacted Johnny Weiss at Solar Energy International, in Carbondale. SEI teaches an excellent series of RE workshops, some of which culminate in a system installation. Johnny immediately called me about the possibility of doing this installation during SEI's wind power workshop, which I teach.

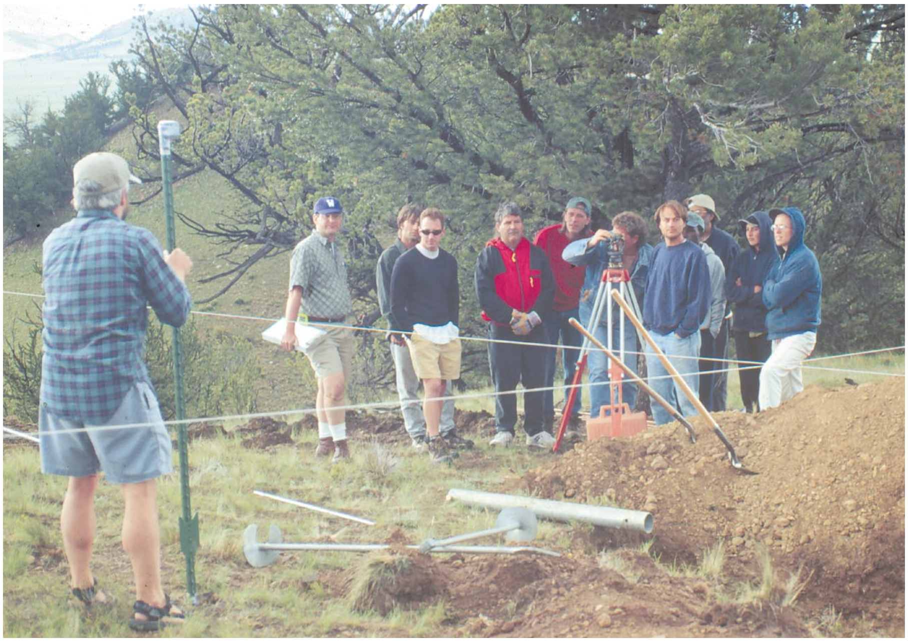
Eric is an accomplished and very professional PV installer. He's also smart, and knows the limitations of one-resource-only RE installations. Eric's offer actually resulted in everyone winning. Lou Ann and Kelvin got a top of the line system installed for a very reasonable price. SEI secured a wind installation for its students. The students received a great lesson in system rehabilitation and a difficult tower installation. And Eric acquired the experience he knew he needed with wind generators and towers.

First Impressions

Based on the pictures and information he supplied about the site, battery bank, and the house loads, Eric and I settled on a Whisper 1500 wind generator mounted on a 60 foot (18 m) tilt-up tower. We decided that the location for the tower would be determined when I arrived in Colorado. I flew in a few days before SEI's wind power workshop began so I could make a site visit with Johnny and Eric.

The first thing that I discovered during our initial site visit was that the Washingtons' house was indeed perched "on top of a hill." In fact, the hill dropped off rather precipitously in all directions. And it certainly was windy! This was going to make for a very interesting tilt-up tower installation.

Johnny Weiss holds a makeshift surveyor's staff while the crew checks anchor heights with a transit.



Setting the anchor orientation amidst a cat's cradle of leveling strings.

The second thing I discovered was that Eric's characterization of the battery room as a "toxic waste site" was no exaggeration. There would be some serious work ahead of us to get the battery room back into a user friendly condition. All in all, this was going to be a challenging installation that neither students nor instructors would soon forget. Johnny, Eric, and I left the site excited with the possibilities.

Work Begins

SEI's Wind Power workshop is a two week program. The first week is spent in the classroom in Carbondale, with forays outside for various demonstrations. Students assemble about nine wind turbines to familiarize themselves with various models and their components. After a week of intense instruction, the students and the instructor are ready to get their hands dirty. Once on site, Johnny, Eric, and I oriented the students and explained the week's work. Even though we had a lot of work ahead of us, we were all anxious to get started.

The first task at hand was to pour concrete for the tower anchors. We had laid out the anchor locations during our pre-workshop site visit. This allowed time for Eric to jackhammer holes in the granite bedrock that hid about a foot below the surface. (Another great lesson! How many PV dealers get to use a jack hammer?) With a group of students in tow, Johnny set up a transit and explained how to use it to determine the tower anchor heights. The rest of us laid out a maze of strings so that we could accurately place the tower anchors in relation to each other.

Setting the anchors for a tilt-up tower is somewhat forgiving on flat level ground. On the side of a hill, anchor location is critical if the tower is to be safely raised and lowered without binding. Binding guy cables can buckle a tilt-up tower in a heartbeat, endangering anyone or anything near it.

Strings and elevations were checked and readjusted numerous times before we were satisfied with their positions. All of this was necessary because once concrete sets, there is no going back for readjustments. Late in the afternoon, the concrete truck labored up to the top of the hill and carefully dumped its load into our holes. We rechecked and readjusted the anchors one last time before quitting for the evening.

Teamwork

The next day, we split into various work groups. One group laid out the underground conduit and wiring from the tower base to the house, then worked on getting the wiring through the concrete wall and into the battery room. We were privileged to have two licensed electricians as students. This helped assure that all wiring, inside the house as well as outside, would be done up to code.

A second group tackled the battery room clean-up and rebuild. After a complete tear-down of the battery room, all acid laden cement, drywall, and lumber were safely landfilled. Needless to say, so were some acid-eaten

Pouring concrete for the tower anchors.

Drilling the battery room walls for tower wiring access. Note the original location of the inverters over the battery box.

clothes. The team then began to rebuild the battery room correctly.

The third group worked on laying out the tower components and assembling the tower. The tilt-up tower was a kit supplied by Lake Michigan Wind & Sun. The tower kit components were all nicely galvanized. However, the four inch (10 cm) tower tube itself, purchased in Denver, needed priming and painting. Since South Park is essentially a desert at a 10,000 foot (3048 m) elevation, the paint was dry after a mere coffee break!

Assembling the tilt-up tower.

Tilt-up Basics

Tilt-up towers are pipe or tube towers, held upright with a system of guy cables. The tower tubes, cables, and connecting hardware are assembled on the ground, then raised into an upright position with a lifting device, such as a tractor, truck, or winch.

A raised tilt-up tower is shaped like the capital letter "L." The long vertical part of the "L" represents the tower, and the short horizontal part represents what we call a "gin pole." The gin pole is the lever used to raise the entire tower into the upright position. When assembling a tilt-up tower on the ground, both parts are horizontal. First, the short part of the "L"—the gin pole—is hoisted into place, making the tower look like an "L" lying on its back.

A lifting cable attached to the gin pole by way of a pulley system is attached to the lifting device—Eric's 4x4 pick-up truck in our case. As the vehicle backs away from the tower with lifting cable attached, it pulls the gin pole into the horizontal position, and the tower into the vertical position. In effect, the gin pole levers the tower into its upright position.

Electronics

The entire house is on AC, powered by three Heart Interface 2,500 watt inverters. The inverters are "cascaded" together, and feed the AC circuit breaker box for the house. Two of the inverters feed up to 5,000 watts at 110 VAC into one side of the 220 VAC breaker box, while the third inverter feeds 2,500 watts at 110 VAC into the other side of the breaker box. Our journeyman electrician from New York City commented that he had never seen anything like this before, but he was unaware of any reason why it couldn't be configured this way.

The inverters were originally located on a shelf about a foot above the battery box. This is not a good situation in any case, but especially not when the batteries are venting acid fumes on an almost daily basis. Ideally, batteries should never be placed in the same room as the inverters, controllers, and other electrical system components.

Unfortunately, it was not possible to totally separate batteries from electronics in this installation. Instead, the team decided to move the inverters and other electronic equipment to the adjacent wall, rather than reinstall them over the battery box. Since this would involve the house being without power for a time, planning and choreography to minimize shut-down time became a consideration. It's real-life challenges like this that make these classes and installations so great!

Untangling the maze of tower guy cables.

While troubleshooting, the students discovered that one of the Trace C-30 charge controllers was not

"Heave-ho"ing the tower gin pole into place.

operating. That meant that only three of the five PV arrays were actually online charging the batteries. The previous owners had limped along, not only on bad batteries, but also with only 600 watts of a 1 KW PV system online! Fortunately, Eric had a spare C-30 that was then plugged into the system, restoring full PV power to the batteries.

The crew built a new battery box complete with a 1 inch (2.5 cm) PVC pipe vent that passed through the concrete block wall. The battery box was constructed very tightly and sealed to eliminate fuming in the

Leveling the tower and tensioning guy cables with a come-along.

battery room. The L-16s were gently placed in the battery box, with anti-corrosion grease coating all battery terminals and interconnects.

Whisper Controller

When the batteries are fully charged, many PV charge controllers simply interrupt the PV to battery circuit, effectively disconnecting the PVs from their load, the batteries. Unlike PVs, most wind generators must have a constant load connected to them. Breaking the circuit between the wind generator and its load results in a freewheeling wind generator rotor. This can sometimes lead to thrown blades.

The Whisper controller is a "shunt" regulator. As the batteries charge up, a resistive load is progressively added to the wind generator/battery circuit. Excess power that the batteries can't take from the wind turbine is shunted to this resistive load. This accomplishes two important things. First, it taper charges the batteries as they reach full charge. Second, it maintains the load on the wind generator, preventing the rotor from freewheeling and possibly self-destructing. A bonus is that the waste heat can be used to heat hot water, or warm your battery room in the dead of winter.

Since wind generator dump loads can get extremely hot, it is critical to install them on a fireproof surface. While this point is stressed in the Whisper installation manual, many folks still install dump loads on plywood instead. With safety in mind, the team mounted both the Whisper controller and dump load on the concrete block wall of the battery room.

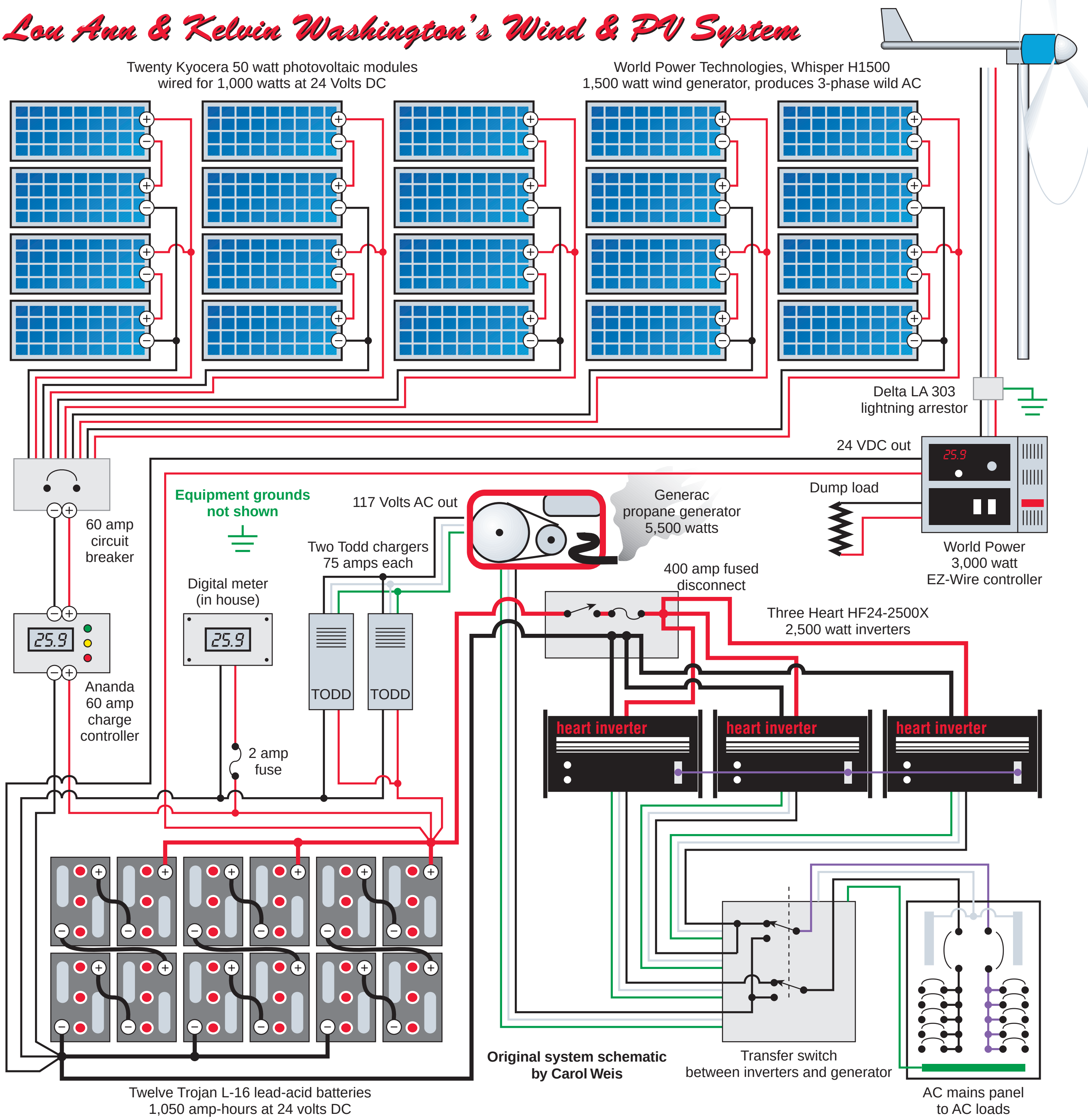
One last feature of the Whisper controller is the wind generator brake switch. Most of today's wind generators are three phase AC permanent magnet alternators. The AC is rectified to DC in the controller for storage in the batteries. By shorting out the three AC phases coming from the wind generator before it is rectified to DC, a very large electrical load is placed on the wind generator. The electrical load is so large, in fact, that the wind turbine's spinning blades are stalled. This action is similar to stepping on the brake pedal in your car, which "loads" the car, so to speak, reducing its speed until the car comes to a stop.

The brake switch is a nice addition to a wind system. It allows the owner to stop the wind machine from the comfort of the control room for any number of reasons: when inspecting or servicing the wind turbine or controller, when the batteries are fully charged, when a storm is approaching, or when leaving the system unattended or unused for long periods of time.

Back Outside...

Meanwhile, the team working on the tower assembly had finished their task. The tower was ready for its initial raising. Since we didn't have a winch, we hitched Eric's 4x4 pick-up truck to the lifting cable, and began slowly raising the tower. Halfway up, we discovered yet another problem—a tree was in the way of some of the guy cables. This was not evident when we laid out the anchors, tower, and guy cables. Fortunately, with a bit of limb

Lou Ann & Kelvin Washington's Wind & PV System



trimming (by *Home Power* staffer and tree monkey Ian Woofenden), we were able to make the guy cables clear the tree. Another valuable lesson while doing a real life installation!

Next came the rather tedious business of plumbing the tower by tensioning the many guy cables. The lower guy cables are always tensioned first. Then the other guys are done, moving progressively to the top. This assures that the tower will stand straight without buckling. Once the tower was plumbed and all cables properly tensioned, it was lowered. It was time to install the Whisper 1500, the culmination of the installation.

TGIF

With the tower back down on the ground, we prepped the Whisper 1500 for mounting atop the tower. We connected the wind generator wires to the tower wires with inline butt-type cable connectors. We wrapped the connectors individually with rubber splice tape, the type

Final nuts and bolts check on the Whisper H1500 before we raise the tower.

used on submersible well pumps. The electrical wires coming down the tower are held in place with a wire basket type of strain relief, known as a Kellums grip. This device acts like a "Chinese finger trap," in that the more the wires pull, the stronger it grips. The Kellums grip supports the wires at the top of the tower, preventing their weight from pulling the wires out of the wind generator.

Once the Whisper generator was wired up and bolted to the tower, we installed the blades and tail. We did final inspections on all of the tower cables and fasteners. We checked all wire connections, both at the wind generator and in the battery room. Then we rechecked wind generator fasteners, making sure they were tight. The wind was blowing, and Lou Ann was anxious. Everything was finally ready!

With Eric's 4x4 in position, once again we slowly raised the tower. This time, we had the wind generator on it. Once the tower was upright, several students secured the gin pole to the front anchor, then disconnected the lifting cable. With the Whisper facing the wind, Lou Ann did the honors and turned off the brake switch. The wind genny started spinning and within seconds, the 35 amps from the PVs was accompanied by an additional 35 amps from the Whisper. Wind and sun, as it should be!

Best of all, we finished the entire project by Friday afternoon—concrete, complete tower and wind generator installation, all wiring, plus a total battery room makeover. Quite an accomplishment. But then, it was quite a group of students!

Original System Costs

Components	*Cost*
Twenty Kyocera 50 W PV panels	$7,000
Three 2,500 W Heart HF24-2500X inverters	$3,780
Twelve Trojan L-16 batteries with interconnects	$2,304
Generac 5,500 W gasoline backup generator	$915
Two Todd 75 amp battery chargers	$590
Roof mounts	$525
2/0 and 4/0 cables	$412
Transfer switch	$344
APT 60 PV charge controller	$249
Wiring	$187
Misc wire, lumber, & hardware for battery box	$180
Miscellaneous hardware	$142
400 amp fuse	$125
Total	$16,753

** All costs are presented in present dollar value.*

Wind Upgrade System Costs

Components	*Cost*
Labor	$400*
Whisper H1500 w/ controller & dump load	$3,210
60 foot (18 m) tilt-up tower kit & tubing	$1,995
SEI overhead fee	$500
Concrete	$345
Wiring & conduit (500 feet of #4 AWG)	$307
Excavation	$225
Colorado state sales tax (3%)	$170
Shipping	$128
Misc. electrical parts (lightning arrestor, etc.)	$87
Misc. hardware (Kellums grip, bolts, etc.)	$77
Whisper controller EZ-Wire Center upgrade	N/C
Total	$7,444

** This was Eric's first real wind installation, so he was learning with the rest of the class. He only billed the Washingtons 25 percent of his normal labor rate.*

Cost tables by Eric Westerhoff

Experience Solar Energy International

I have always been impressed by the caliber of student that the SEI wind workshop draws, as well as the diversity of their backgrounds. Most folks are PV dealers and homeowners interested in learning how to integrate wind into their energy mix. But a number of students have other professional interests in the wind workshop. Students have included folks with PhDs in physics, mechanical and civil engineers, licensed electricians, accountants and financial policy analysts, home contractors, and even an oil company executive.

Check out the diverse perspectives of Carol Weiss and Eric Glatstein, students in the 1998 wind workshop.

Carol Weis: Apprentice Electrician

I am approaching the solar world by apprenticing as an electrician. I worked for eight months doing commercial work in Minneapolis before moving to Carbondale, Colorado, in pursuit of hands-on practice in the renewable energy field. I also wanted an electrical job so I could work towards my license. Once in Colorado, I struggled to find an employer in this traditionally male field who would hire a woman electrician. I finally found Patrick Kiernan from Eco Electric in Basalt, who does a combination of solar and regular electrical work.

My goal as an electrician has always been to work in renewables. I've learned to work with tools and wires in the AC world, but I had never worked in the DC world, or with solar panels or wind generators. I have always been a hands-on learner, so taking SEI workshops seemed like the logical choice.

The wind class was my favorite workshop offered by SEI. I loved taking apart the wind generators in class, and it has inspired me to take a motor and generator class here in town. The material covered at SEI was in-depth, current, and easy to grasp. Above all, I enjoyed the blend of personalities which we entertained in the group and the triumphant event of raising the tower and hearing the blades flutter in the wind for the first time.

Eric Glatstein: EPA Engineer

I am an engineer with the United States Environmental Protection Agency's regional office in Chicago, where for the past seven years I have worked on a variety of projects. The subject of radioactive waste is closest to my heart—cleaning up abandoned radium paint from the 1920s, and trying to figure out ways of disposing radioactive material.

Practicing engineers are deluged with notices for continuing education on such topics as limited difference modeling of reinforced concrete under minor earthquake loads, offered in the ballroom of a Holiday Inn just off the expressway. SEI is different. Students learn something, then they get to try it and see the results. After a week in the classroom and several days installing the turbine, I became hypnotized by the blades as they finally began spinning and free power began trickling into the battery. I never would have thought this would be so fascinating to watch.

One reason other engineers may want to try an SEI course—besides spending a few weeks in the Rockies—is to inspire thoughts about innovation. A prediction among people who know far more about the electricity business than I is that the U.S. will not be building any more large generating stations. If this is at all true, the technologies SEI teaches will become increasingly significant.

Since Then...

On Christmas day, Kelvin came home to the smell of smoke in the battery room. The Whisper controller had overheated and self destructed. Thank goodness for cement block walls. Yet another lesson—electricity can cause fires! The decision to mount the Whisper controller and dump load on the cement block wall was a good precaution. As Eric said, "I don't want to be responsible for someone's house burning down."

Whisper wind generators have a reputation for producing more than their rated power. Lou Ann reported that she has seen the Whisper's peak output hit 79 amps. With a 24 VDC nominal system voltage, charging often reaches 30 VDC. That's more than 2,300 watts going through the 1,500 watt controller and into the dump load. Eric wisely replaced the 1,500 watt controller with a 3,000 watt controller.

Eric also replaced the two Trace C-30 PV controllers with an Ananda 60 amp charge controller. In addition, he added a PV circuit breaker switch between the PVs and the Ananda, something the original PV system lacked.

Satisfied Customers

Lou Ann is thrilled with their wind/PV hybrid system. With the exception of the down time they experienced

Class photo of the crew with an almost complete installation.

when the Whisper controller fried, the Washingtons have never run their backup generator.

Besides the normal AC electric loads like a deep well pump, the household appliances include a dishwasher, washing machine, and a high efficiency 22 cubic foot (0.62 m^3) Amana frost-free refrigerator. Most of their heating loads (furnace, water heater, clothes dryer) run on propane. Even so, Lou Ann reports that they have "more electricity than they know what to do with." She says that when the wind really blows, she runs around the house turning on lights rather than shutting down the wind generator. With no sun or wind, the Washingtons have four days of battery storage.

An enthusiastic Lou Ann throws the final switch, starting up the wind generator.

When he first met them, Eric said that neither Lou Ann nor Kelvin knew an inverter from a PV module. Now, Lou Ann calls him to discuss charge controller regulating voltage versus inverter shut-off voltage. Notes Eric, "You couldn't ask for better customers. They want answers, and they're involved with their system."

The system has come a long way from the days when the 8.5 KW generator had to be run just to turn on a light at night. And according to Eric, so have Lou Ann and Kelvin. With a smile in her voice, Lou Ann said, "I've learned a lot. I'm in charge of my own electric system. I can't imagine ever living on the grid again."

Access

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Fax: 970-963-8866 • sei@solarenergy.org
www.solarenergy.org

Equipment suppliers:

Lake Michigan Wind & Sun, 1015 County Rd. U, Sturgeon Bay, WI 54235-8435 • 920-743-0456
Fax: 920-743-0466 • lmwands@itol.com

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It could take five to ten years for comparably rated monocrystalline modules to generate the electricity equal to that used in their production. Note: Computer simulation showing comparably rated monocrystalline system and its frame.

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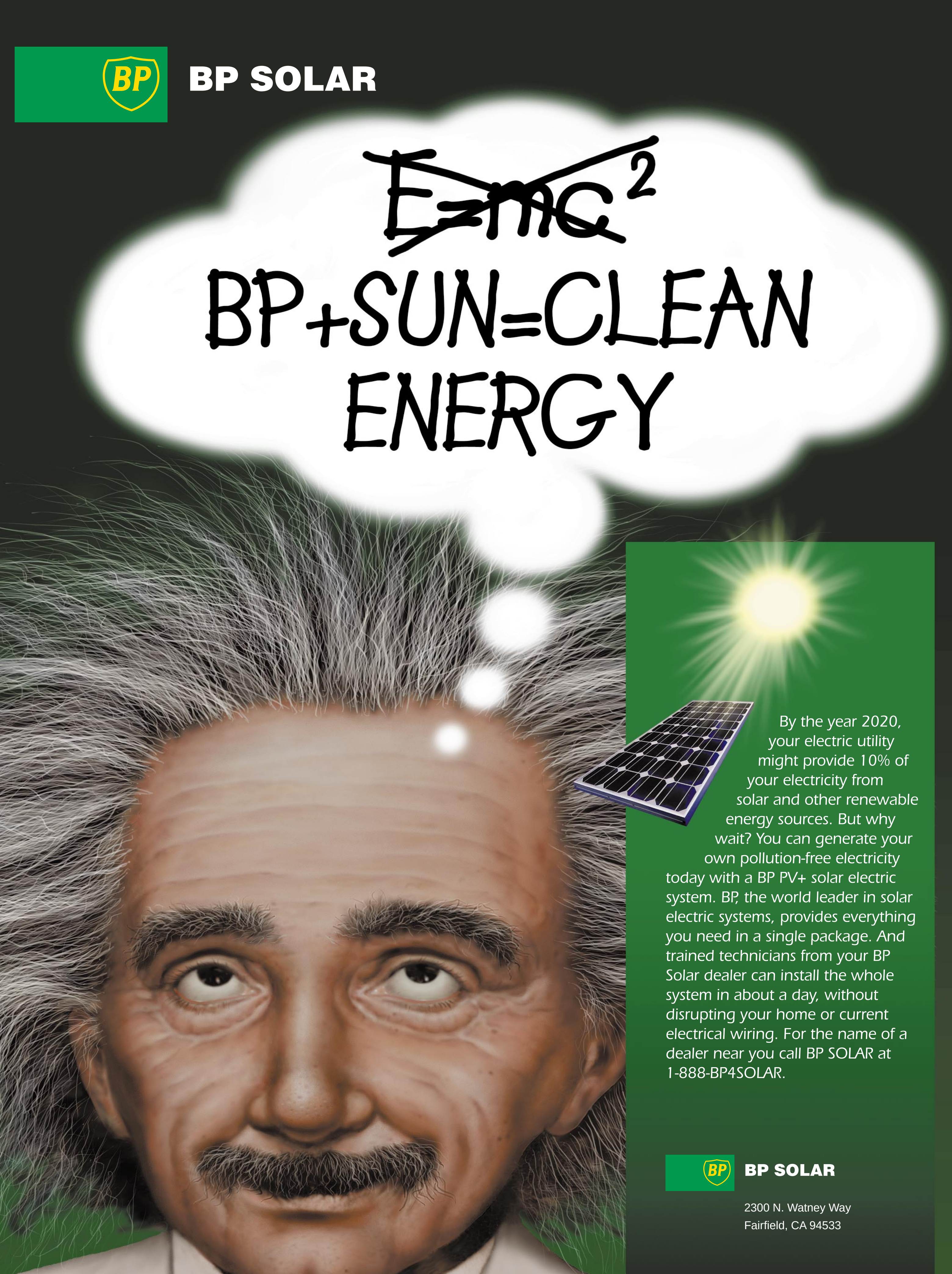
SOUTHWEST WINDPOWER

full page
four color on negatives

this is page 34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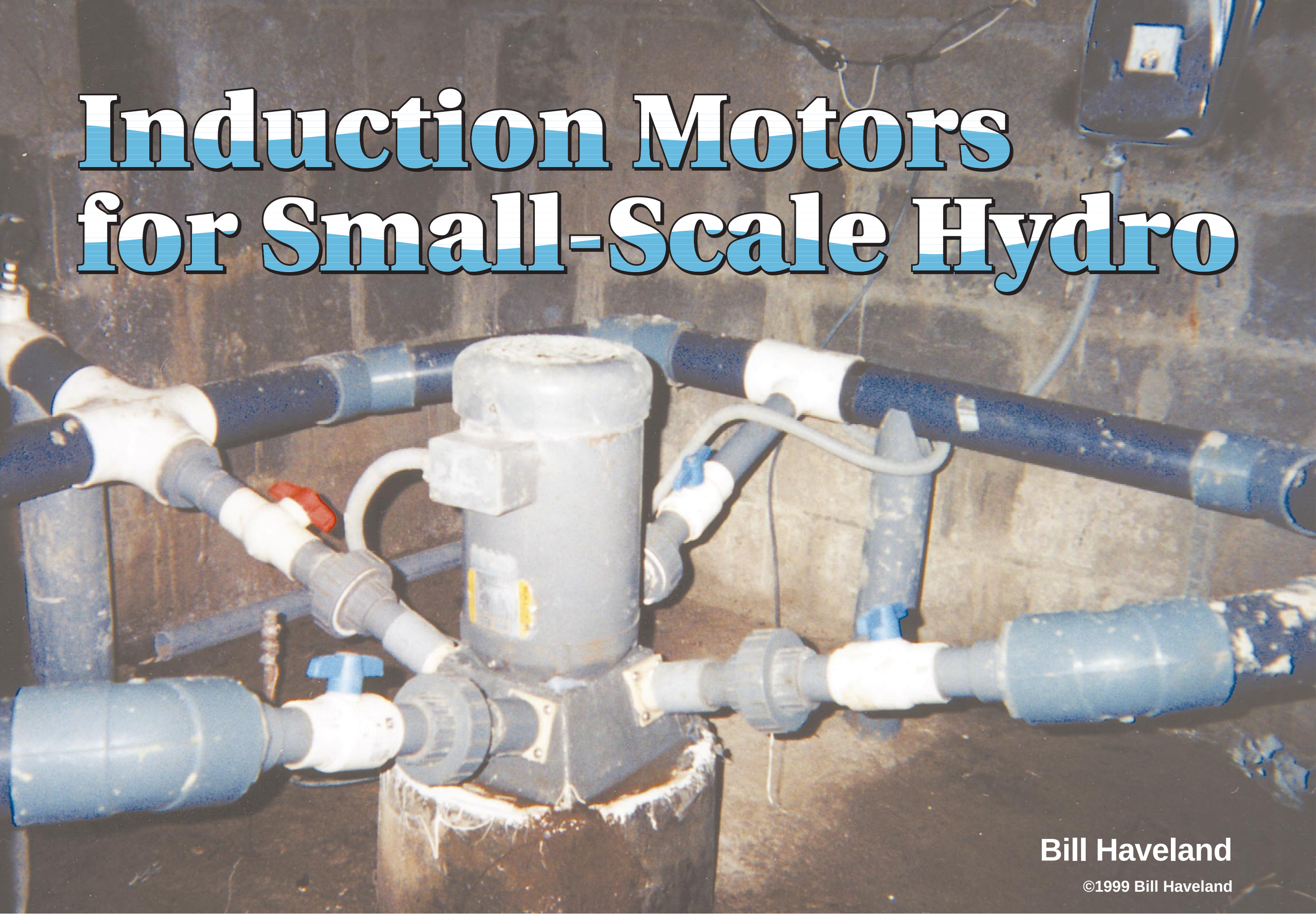
Induction Motors for Small-Scale Hydro



Bill Haveland

Richard & Nancy Lebo's 2 HP induction motor making juice in Costa Rica.

The standard three-phase induction motor is very well suited for hydroelectric generation. These motors, functioning as generators, can be used for both battery charging and stand-alone applications.

Induction motors are especially useful on streams and springs situated a long distance from where the power will be used. Excessive wire loss in these situations makes transmitting low voltage functionally impractical. The generation voltage of induction generators is typically from 120 to 480 volts, compared to the 12 to 48 volts of the small turbines commonly available on the market. This technology opens up many potential generation sites that were not previously usable with existing turbines.

Economical & Low Impact

A 1 1/2 horsepower (HP) induction motor, generating at 500 watts, produces about 12 KWH per day, which is equivalent to fifty 75 watt PV panels installed in Phoenix, Arizona. The PV panels would cost nearly $18,000; the hydro turbine generator would only cost about $2,000. Where the water resource exists, and local legal and social structures allow its use, battery charging hydro is almost always the most economical source of off-grid power.

With careful site development, small hydro installations, which generally do not use large impoundment structures, have a very low environmental impact. Where there are other creatures using the same water, consideration for their well-being should be practiced in all stages of development and operation.

Richard & Nancy in front of their hydro-powered home.

This article presents an overview of the technology with its advantages and disadvantages. For more on induction generator theory, see *HP3,* page 17, and sources at the end of this article. I've listed some of the pitfalls that I've learned from experience, and included a simplified development procedure to help you put your own hydro to work. Sources, suppliers, and references are listed at the end of the article.

Advantages of Induction Generators

1. Readily Available
Three-phase induction motors are readily available nearly everywhere in the world—new, used, or reconditioned. These motors are manufactured in a wide variety of voltages, efficiencies, case types, service applications, and rpm configurations. This makes it possible to locate a motor to fit nearly any site, except those with very low head.

All motors used as generators in hydro applications should be of the totally enclosed fan-cooled (TEFC) type, with severe duty motors preferred. C-face motor mounting is usually used for direct coupling the motor to the runner. Harris Pelton or four inch (10 cm) Turgo runners are the products generally selected for most home-scale battery charging applications. The C-face mount limits the selection of suitable motors somewhat. High-power turbines or motors with standard mounting can be belt coupled, through a jack shaft, to the turbine runner.

The C-face motor is designed for bolting the turbine housing directly to the shaft end of the motor. Adapting the Harris or Turgo turbine runners to the selected C-face motor will require one of three things: making a coupling adapter, ordering the turbine runner with a keyway the same diameter as the motor shaft, or machining the motor shaft to match that of a Ford alternator. Ford and Delco are the most commonly used high output automobile alternator models in microhydro applications, and most runners are built with shaft sizes to fit them.

2. Inexpensive
A new, premium-efficiency, severe duty, 1 1/2 HP, 1,800 rpm, 230 V/460 V, 56C-face, TEFC, three-phase motor will cost US$200 to $450. These motors are also available reconditioned at a significant discount. This initial cost is similar to the DC Ford and Delco alternators now used on small hydros, but these alternators require frequent rebuilds and have a limited life expectancy.

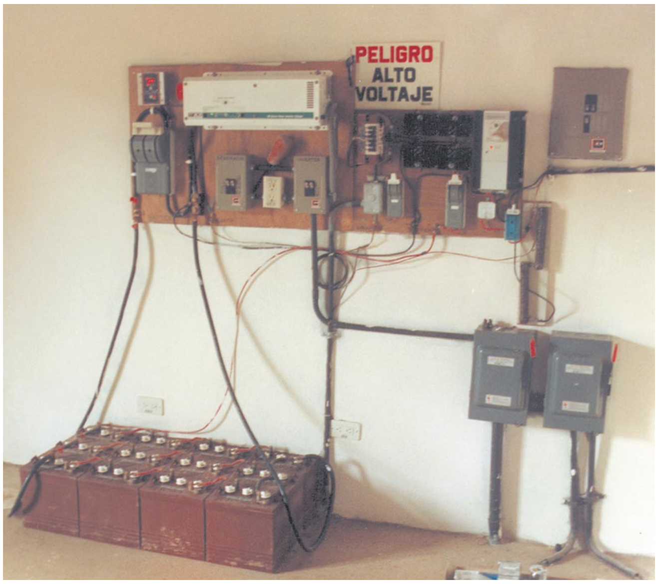
The complete hardware package of an assembled turbine for a 1 1/2 HP motor—induction generator, capacitors, capacitor enclosure, fuses, transformer, and rectifiers—will cost about US$2,000 to $2,500. Where

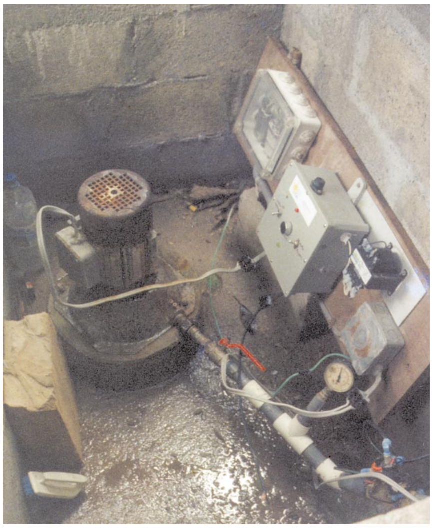
A typical filter tank at the top of the Lebos' penstock.

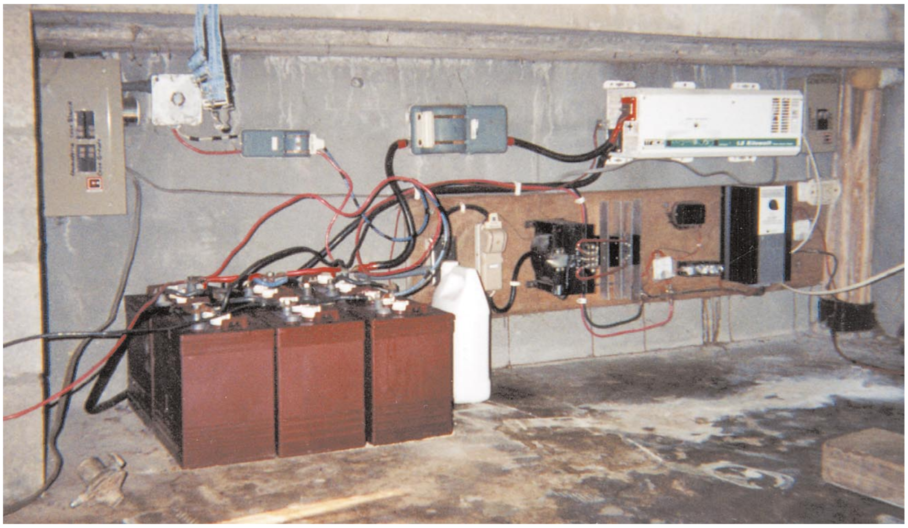
the turbine is closer than 500 feet (152 m) to the batteries, the less expensive (US $900–1,400) and more efficient low voltage DC alternator should be used. The additional cost of the induction machine can be attributed to components that are unneccesary with the low voltage DC machine. These include capacitors, transformer, protection devices, wiring, and rectifiers with their enclosures. Though induction generators are somewhat more expensive up front, they can outlast conventional alternators many times over.

3. Very Robust
These generators will last decades, with bearing replacement every three to five years of continuous service, if they are set up properly to begin with. The

At the DC end, 258 V is stepped down to 24 V.







The Bosque del Cabo system utilizes a 1 1/2 HP motor (left) to produce 180 watts from 21 gpm at 190 feet of head. 2,300 feet from the hydro unit, the rest of the system (right) steps down from 415 VAC to 12 VDC.

motor design is meant to withstand many years of industrial use and abuse. There are no brushes, slip rings, diodes, or wire windings on the rotor to fail.

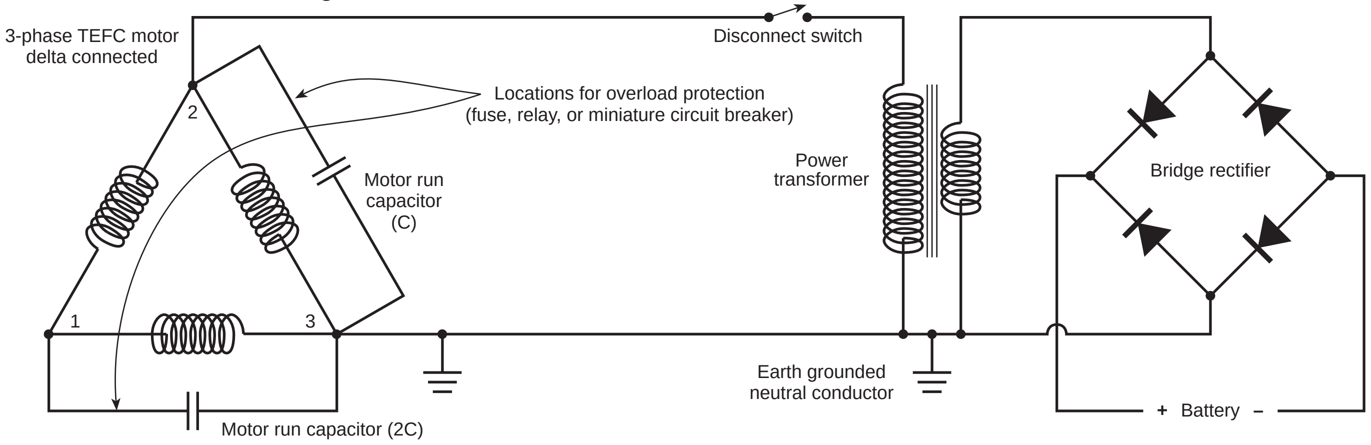
Not having windings on the rotor allows the generator to tolerate significant sustained overspeed without damage. The sealed machine housing provides excellent protection against dust and liquids. Induction generators will survive serious mechanical and electrical abuse that would kill automotive alternators.

4. Inherently Overload Protected
Sooner or later, a short circuit will be applied to the generator output. This might be caused by shorted wires in the transmission line or defective components in the battery charging system. With this type of failure, the generator will lose excitation and spin freely without suffering damage. If an overload occurs in the distribution of a stand-alone system, it will also cause the generator to lose excitation and begin to freewheel.

In contrast, a turbine using a Ford or Delco alternator subjected to a short on the output will cause the alternator to burn up. The induction generator will not restart until the overload is corrected. Although induction motors are inherently overload protected, runaway overload protection is necessary to protect against a disconnected load. This scenario is dealt with under *Disadvantages of Induction Generators.*

5. Can Generate at a High Voltage
Because induction motors generate at high voltages, long distance transmission is possible using light gauge, inexpensive wire. For example, a 575 volt motor generating at 480 volts can transmit 750 watts with 5 percent voltage loss for one mile (1.6 km) on two strands of #12 (3.3 mm^2) wire. This high voltage generation, transmitted over inexpensive wire, makes it possible to harness streams previously deemed too far away for battery charging hydro.

Induction Generator Wiring



Induction Hydro System Comparison

Owner	*Bosque Del Cabo Lodge*	*Buena Vista Lodge*	*Casa Corcovado Lodge*	*Richard & Nancy Lebo*	*Joel Stewart & Belen Momene*	*German Llano*
Motor manufacturer	Brooke Hansen	Brooke Hansen	Brooke Hansen	Baldor	Baldor	ESD (3 Phase Alternator)*
Motor rpm	3,600	1,800	1,800	1,200	1,200	N/A
Motor HP	1.5	1.5	1.5	2	2	N/A
Motor volts	575	575	575	480	480	N/A
Generation volts	415 VAC	415 VAC	386 VAC	258 VAC	334 VAC	28 VDC
Generation hertz	66	65	71	85	70	N/A
Test flow	21 gpm	55 gpm	60 gpm	300 gpm	185 gpm	73 gpm
Test net head	190 ft	81 ft	148 ft	55 ft	65 ft	55 ft
Net water potential	750 watts	840 watts	1,670 watts	3,100 watts	2,250 watts	760 watts
Turbine manufacturer	Harris / Pelton	Harris / Pelton	Harris / Pelton	ESD / Turgo	ESD / Turgo	Harris / Pelton
Turbine / generator efficiency	28.0%	50.0%	26.9%	17.1%	32.9%	60.5%
Transmission line efficiency	90.5%	97.6%	95.6%	90.6%	94.6%	97.8%
Transmission line length	2,300 ft	2,500 ft	1,600 ft	1,300 ft	1,100 ft	300 ft
Transmission line gauge	#12	#12	#12	#12	#10	#2
Transformer efficiency	97.4%	96.3%	97.7%	89.6%	95.7%	N/A
Rectifier efficiency	98.9%	93.7%	97.6%	88.8%	94.0%	N/A
System voltage	12 VDC	24 VDC	24 VDC	24 VDC	24 VDC	24 VDC
Overall efficiency	24.4%	44.0% **	24.6%	12.3% ***	28.0%	59.2%

* *For reference only, this is not an induction generator.*
** *Without retesting, no explanation can be found for this abnormally high efficiency.*
*** *Poor efficiency likely caused by an old installation using two equal size capacitors connected instead of C-2C configuration, or a locally made transformer.*

Disadvantages of Induction Generators

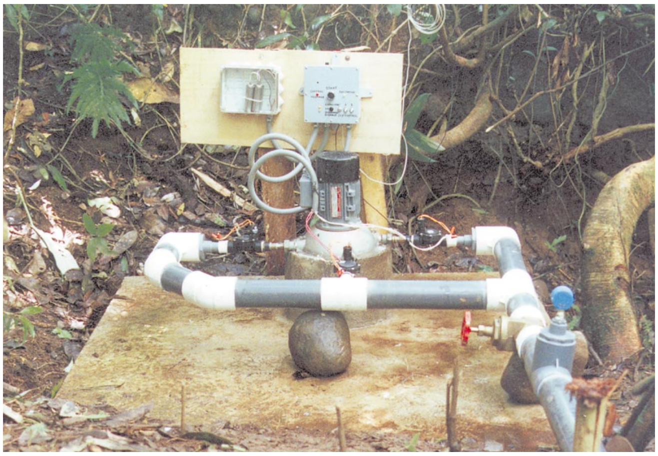
1. High Voltage!
Danger! Great care should be taken working with the 240 to 800 volts AC that these units generate. It can be lethal at worst, and at the least, it's memorable.

2. Initial Setup
With this system, capacitors must be connected to the motor to supply excitation current, allowing the motor to become a generator. *Danger!* To prevent electrical shock, the excitation capacitors need to have a 1 megaohm, 2 watt discharge resistor connected terminal to terminal.

The connection method calls for "C" amount of capacitance across the phase where the output is taken and "2C" across the other phase (see diagram). As an initial value of capacitance, use 3 µF per motor HP for "C" and 6 µF per HP on the "2C" phase.

To maximize efficiency, capacitor sizing needs to be done on a trial and error basis. The machine should be installed in its permanent site or with site conditions duplicated in a test situation. A clip-on ammeter, with a low scale such as 0-6 amps, is ideal for the procedure detailed below. If a clip-on meter is not available, the 10 amp range found in most multimeters will work, but the user will need a lot of patience and care. Each measurement will require shutting down the turbine and opening the circuit to allow connection of the meter for amp measurement.

When the three phases are combined into a single phase wire pair, then the electrical direction of motor rotation must be determined. The capacitors need to be connected between the correct phases for the rotational direction. First connect the motor as shown in the diagram. Carefully measure the current in the ungrounded output wire and note the result of the measurement. Change the 2C capacitor connection point from 3 to 2, leaving 1 connected. Again measure the current in the output wire. If the current is higher than in your first measurement, leave the capacitor in



The Buena Vista Lodge uses a 1.5 HP motor to generate 370 watts from a three-nozzle pelton wheel.

415 VAC becomes 24 VDC at Buena Vista's power center, 2,500 feet from the Harris hydro unit.

this position. If the current is lower than in your first measurement, return the connection to point 3.

The current in each motor lead should be checked for balance. Each leg needs to be within 30 percent of the others. Do not, under any circumstances, let the current exceed the motor nameplate rating for the selected wiring configuration. Most three-phase motors have dual voltage connections. For example, a nameplate rating list may show 2 amps for the 480 volt configuration and 4 amps when connected for 240 volts. So if the motor is wired for 480 volts, the 2 amp plate rating is the maximum allowed per phase even if the generation voltage is only 240 volts.

Capacitor substitution for the initial values will correct phase imbalances if they exist. It is very helpful to have industrial electrical experience for this process, but handy people with a good knowledge of electricity can usually muddle through it. A selection of motor run capacitors is necessary for maximizing machine output. This is a fairly significant cost outlay—about US$200—and you will end up with some extra capacitors when you're done.

Casa Corcovado Lodge gets 410 watts from 60 gallons per minute at 148 feet of head.

3. Low Generating Efficiency
Thomson and Howe is a company in British Columbia, Canada that did much of the early work on induction hydro generation. They reported efficiencies between 86 and 95 percent for three-phase induction motors used as generators. My experience does not confirm these efficiencies. The highest efficiency I've seen was achieved with a stand-alone system using a 10 HP motor, and that was about 70 percent efficient. It is tempting to assume that the larger HP motors produce higher efficiencies, but additional experimentation is needed. Most motor catalogues will list the efficiency of the product. Generally, the higher efficiency models will also produce an increased efficiency when used as a generator.

The 1-2 HP motors generally used for battery charging systems have produced efficiencies in the 25-35 percent range. This is significantly below the 50-60 percent that a properly installed Ford or ESD generator will produce. But the more efficient low voltage DC units are not practical for transmission distances over 800 feet (244 m) in 48 volt systems. For lower voltages, maximum transmission distance is considerably less. For sites with long distances, the practicality of the high voltage induction generators outweighs the lower efficiency.

4. Load Disconnection Runaway Overload Protection
Overload protection should be used on generators run near their output limit. When runaway occurs because of load disconnection, if the capacitors remain connected to the generator, both the voltage and

current will rise. The motor has an information plate that indicates its maximum current per phase. If any of the individual phase currents exceed the nameplate maximum current at runaway, then controls need to be installed. The controls disconnect the capacitors from the motor, allowing it to freewheel.

Joel Stewart and Belan Momene are building a hydro-powered lodge. Currently, their system provides 15 KWH per day.

When the capacitors are disconnected, the generator voltage will collapse. This control circuitry can take several forms. The simplest is a 600 V fuse in series with each of the two capacitors in the C and 2C format (see diagram). This fuse should be no larger than the rating of maximum current on the motor plate. Miniature magnetic circuit breakers can be used in place of the fuses if loss of load is a common occurrence. With an additional level of control circuitry, the capacitors can be disconnected from the motor if either a high or low voltage occurs on the output. This same circuitry can actuate water valves that can shut off water flow to the turbine.

AC motor run capacitors with a voltage rating that exceeds the runaway voltage should be used. Newark Electronics has 660 VAC motor run capacitors that will withstand the peak runaway voltage on all but the 575 V induction generators.

When capacitors are not available with the correct voltage rating, lower voltage units can be used in series. With this configuration, the voltage rating of the capacitors will be additive. The capacitance is calculated with the formula 1/C total = 1/C1 + 1/C2 + 1/C3. Example: Two 440 V, 10 µF capacitors in series would then be 880 V, 5 µF.

5. Large Inductive Loads Need Power Factor Correction

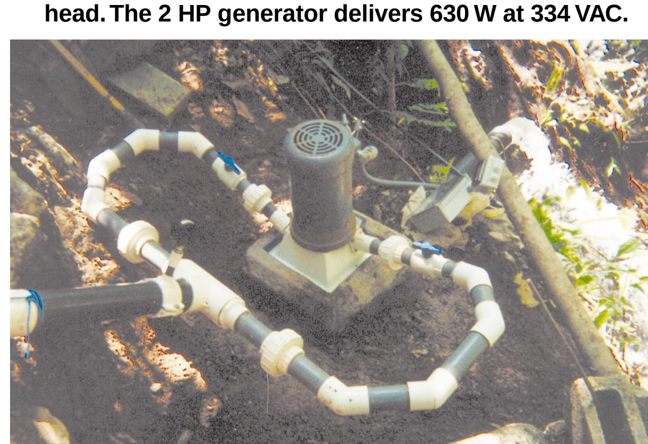
Stand-alone induction generators have difficulty running inductive loads such as motors. A stand-alone induction generator directly runs the loads and does not use batteries or an inverter. These systems require more sophisticated electronics to operate, in the form of a load controller with ballast resistors, which hold the voltage and frequency near 60 Hz 120/240 volts. The motor load inductance reacts with the generator's excitation capacitors, causing the voltage to fall and the frequency of generation to rise. If too large an inductive load is connected, it will cause the generator to lose excitation. To correct this problem, motors run directly on stand-alone induction generators should be power factor corrected with both start and run capacitance.

6. Generator May Lose Residual Magnetism

Loss of residual magnetism occurs when the generator is rapidly shut down with a load connected, loses excitation because of an overload, or more often from running down (blocked intake water filter) with a load on. Residual magnetism is present in the iron core of the rotor. This allows the motor and capacitors to begin generation, which subsequently builds up to its normal voltage level.

If this magnetism is lost, it can be restored by connecting a simple 9 V radio battery between any two of the motor leads for a couple of seconds. The iron core material used in high efficiency motors holds less residual magnetism, so these motors are more susceptible to this minor problem.

Joel and Belan's turbine receives 185 gpm with 65 feet of head. The 2 HP generator delivers 630 W at 334 VAC.



Experience Is The Best Teacher

Sistemas de Energia Eficientes is the company I operated in Costa Rica for eight years. We installed six induction generating systems there in the last five years, and maintained an additional unit. See the system comparison table for details on these systems.

Experience is the name we give to our mistakes. The good news is that all of the systems are still working and the clients are very happy with them. The bad news is that it took making some mistakes to gain lots of experience. These are some of the lessons we've learned through the school of hard knocks:

• The jungles of the third world are not the place for product experimentation. The same applies, to a lesser degree, to field conditions in developed countries.

• Standard transformers and water valve solenoids work best at 60 Hz or above. The net head, turbine type, wheel diameter, and motor nameplate rpm need to be selected to allow the generator frequency to be within 55-75 Hz.

• Keep it simple—Murphy's Law is always enforced eventually. Use the simplest protection controls that will do the job, which usually means 600 volt fuses on the two capacitors. The operator of the plant must understand what occurs at runaway and why the fuses blow, and needs to have spares on site. If the phase current exceeds the nameplate value during loss of load or runaway, the motor is at risk of burning up. This is when the controls need to be used, a smaller turbine jet installed, or a larger motor selected.

• The motor generation voltage is determined by a chain of system components. The links in this chain are battery voltage, rectifier type and configuration, the main step-down transformer, and to a lesser extent, the resistance losses in the transmission line from the generator to the transformer. These must be carefully selected or system frequency and voltage may be drastically different than the design value. Low generation voltage and frequency will cause problems. If this happens, transformers will not operate as efficiently and water valve solenoids may not fully actuate, resulting in control transformer failure.

• Don't skimp on the penstock size; larger is always better. Black poly pipe, at least the pipe manufactured in Central America, has very high frictional losses. For this reason, I do not recommend it for hydro installations. PVC works very well but contains vinyl chloride, which is not at all good environmentally. Does anyone out there have experience with ABS and a knowledge of its toxicity?

• Shottky rectifiers should not be used with these systems. They cannot withstand the runaway voltage present if someone removes a battery cable while the turbine is generating.

Step-Down Transformers

High voltage from the generator needs to be lowered to the nominal battery voltage. A single-phase transformer is used, but it must be carefully selected for efficiency and proper voltage rating. Custom made high efficiency transformers are usually used on these systems. GE does make a production model with 480/240 primary and 48/24 secondary. They come in 0.75 and 1 KVA sizes retailing for US$294 and $370. These would function for 1 1/2 and 2 HP motors of 575 and 480 volts. The downside of production models is that they do not have multiple taps on the primary, which assist in maximizing output efficiency.

Generally, a motor can be used as a generator at voltages from 50 to 85 percent of the motor nameplate rating. For example, a 1 1/2 HP, 240/480 V, 1200 rpm motor is selected and connected as 480 volts. A custom transformer that would match this motor could be specified as 0.75 KVA, with primary voltages of 240, 280, 320, 360, and 400, and secondary voltages of 24 or 48 (depending on battery bank voltage), center tapped. If the GE production model is used, the 240 volt primary must be used. But custom wound, high quality transformers can be obtained at a cost very similar to the GE production models.

Site Evaluation

A thorough and accurate site evaluation should be the first step to any hydroelectric project. Everything you find on the subject will basically get you two numbers: *net head* and *flow*. It is very important that the analysis is accurately done, since the whole hydro project is designed around these numbers.

Step by Step Procedures

1. Determine whether or not there are legal or social obstacles to using the stream water. Get the permits or understand the risk.

2. Accurately determine the gross and net head available, and the water flow. An average yearly flow and minimum flow will be sufficient in most cases.

3. Calculate net stream potential using this formula:

$$P = H \times F \times E \div 100$$

Where P is power in watts (stream watts net), H is gross head in meters, F is flow in cubic meters per second, and E is overall efficiency.

Overall efficiency is expressed as a decimal, and includes penstock, turbine, generator, wire, transformer, and rectifier losses. A number that can be used for the efficiency of small stand-alone induction systems of less than 5 KW is 0.4 (40%). For battery charging configurations, 0.3 (30%) is appropriate.

4. Determine load in both KWH per day and peak KW. If the potential of the stream is equal to or greater than the peak KW needed, consider a stand-alone installation. A battery charging system is generally less than half the cost of a stand-alone system for the same peak KW. A properly installed stand-alone system is more reliable because it does not use batteries or inverters. It will also produce considerable excess power that can be used for water heating, etc.

5. If the turbine end of the penstock (pipe from water intake to turbine) is located farther than 500 feet (152 m) from the area where the power needs to be used, then an induction generator should be considered. If an induction machine is applicable, select the motor rpm and HP that is appropriate for the hydro resource available and the load needed.

See the rpm selection chart for induction motors used in battery charging systems. It assumes that the turbine runner diameter is four inches (10 cm). Try to stay as near as possible to the "ideal" shown in the chart. These ranges need to be experimentally verified under laboratory conditions, especially the minimums and maximums. Is any reader out there looking for a university thesis project?

German Llano's filter tank, at the top of 55 feet of head, provides a clean 73 gallons per minute.

Motor RPM Selection Table

Motor rpm	*Head in Meters*		
	Minimum	*Ideal*	*Maximum*
3500	60	80	150
1800	20	40	80
1200	12	20	40
900	6	10	20

6. To select the horsepower of the motor using the average stream flow, determine the potential of the stream in watts. Next, divide this number by 745 watts, which will give you theoretical motor HP. But the motor will not produce as a generator what it consumes as a motor. To derate a small motor under 3 HP used as a generator, divide the resultant motor HP rating by 0.75. This will give you the actual motor HP needed. Here it is in one formula:

$$HP = P \div 745 \div 0.75$$

Where HP is the necessary rating of the motor in horsepower, and P is stream watts net.

Additional Technology Development In Process

I am now experimenting with the excitation and synchronization of the induction generator to the output of Trace sine wave and modified sine wave inverters. This has the potential to decrease the number of components required and the associated costs, while at the same time increasing the efficiency of the generation process.

Resources

Technical information on selection, purchase, setup, installation, and maintenance of induction generators is difficult to obtain. Very few publications exist describing this useful technology. The exception is one excellent book, still in print, from IT Publications in England,

Llano's ES&D 28 volt DC alternator acted as the control group in the comparison of AC induction generators.

Motors as Generators for Micro-Hydro Power. In the Access section, you'll also find information on one company in Canada and two in the U.S. which offer assistance and sell equipment.

There are many books available on the subject of hydro site analysis. I highly recommend *Micro-Hydropower Sourcebook* and *Micro-Hydro Design Manual.* Both of these books are references on most facets of a hydro project and are well worth the expenditure. Also, see articles that deal with this topic in *HP42,* page 34, and *HP44,* page 24.

An excellent and accurate shareware computer program that is very easy to use is available for hydro site analysis. Preferred Energy Resources can supply this program for $10, which covers copying and mailing costs.

Care and Attention

I would like to advise care and attention to detail in all aspects of the design of microhydro installations, especially the civil works. A properly designed and built project will last a lifetime. Unfortunately, there are many installations abandoned shortly after they are built because of improper engineering or construction. So do it right, and if you have questions, seek professional help.

If the site parameters and budget lend themselves to a battery charging hydro but the water source is too far away for a DC turbine, then a high voltage induction generator should be able to satisfy the need. If properly engineered and installed, it will provide many years of clean reliable electricity at a fraction of the cost of other renewable energy options.

Access

Induction motors, turbines, transformers, rectifiers, and technical assistance:

Bill Haveland, Preferred Energy Resources L.L.C. (formerly Sistemas de Energia Eficientes SEESA), 3032 County Road 7, Grand Marais, MN 55604
218-387-2160 • Fax: 218-387-2173
bhaveland@boreal.org

Alternative Energy Engineering, PO Box 339, Redway, CA 95560 • 800-777-6609 or 707-923-2277
Fax: 800-777-6648 or 707-923-3009
jay@alt-energy.com • www.alt-energy.com

Stand-alone turbine manufacturer, using synchronous generators: Canyon Industries, 5346 Mosquito Lake Rd., Deming, WA 98244 • 360-592-5552
Fax: 360-592-2235 • CITurbine@aol.com
www.canyonindustriesinc.com

Stand-alone induction experts with the most experience in North America: Thomson and Howe, Site 17, Box 2, S.S. 1, Kimberley, BC, Canada V1A 2Y3
250-427-4326 • Fax: 250-427-3577
thes@cyberlink.bc.ca • www.smallhydropower.com

Micro-Hydropower Sourcebook, 1999. Allen Inversin, NRECA. US$26 postpaid from NRECA International Foundation, Mail Code IPD9-202, 4301 Wilson Boulevard, Arlington, VA 22203-1860
703-907-5637 • Fax: 703-907-5532
allen.inversin@nreca.org • www.nreca.org

Micro-Hydro Design Manual, 1993. Adam Harvey, IT Publications. $55 from Stylus Publishing L.L.C., PO Box 605, Herndon, VA 20172 • 703-661-1581
Fax: 703-661-1501 • styluspub@aol.com

Motors as Generators For Micro-Hydro Power, Nigel Smith, IT Publications. $12 from Stylus Publishing L.L.C. (see above).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Decide for Yourself!

Without the need for flashy product pictures and fancy marketing ploys, we would like for you to decide which inverter will be trusted in your home. These laboratory test results intend to clear up misconceptions and illustrate an accurate comparison between Trace Engineering's SW2512 and the Statpower PROsine 2.5. Knowledge is power and so is a highly efficient inverter with low idle power consumption!

SW III

	TRACE SW2512	Statpower PROsine 2.5
Idle Power Consumption	13 watts typical	60 watts typical
Efficiency		
100 watts AC load	88%	62%
200 watts AC load	91%	71%
500 watts AC load	93%	84%
1500 watts AC load	88%	88%
Peak efficiency	93%	88%
AC output waveform distortion	Less than 5% / typical 2%	Less than 5% / typical 2%
Number of 50 Watt PV modules to meet inverter's idle power Draw without use of search mode	1.3 PV modules in summer 3.1 PV modules in winter	5.8 PV modules in summer 14.4 PV modules in winter
Search Mode Power Consumption	Less than 1 watt	3 watts typical
Response time to AC loads coming out of search mode	Less than one second	Up to three seconds
Search mode adjustability	0 to 256 watts, via LCD control panel	0, 12, 25 or 50 via micro-switches on side
Ability to override search mode without changing control settings	Yes	No
Battery charger rating	150 amps DC	100 amps DC
Battery type compatibility	Fully adjustable bulk, float & equalize voltage. Adjustable absorption & equalize timers	Micro switch for sealed or vented battery type. Fixed absorption and equalization settings.
Battery Temperature Sensor	Standard	Optional
Synchronous AC operation	With utility grid or generator AC sources	Not available
AC transfer switch capacity	60 amps AC	30 amps AC
AC Inputs	Two - separate generator and utility grid inputs	One
Maximum AC pass-through with full battery charger operation	35 amps AC	9 amps AC
Maximum generator input power	7.2 kW	3.6 kW
AC input amps adjustment	1 to 60 amps AC in 1 amp increments	10, 15, 20 and 30 amps AC current settings
AC lower voltage limit	Adjustable	Fixed at 90 VAC
Standard display / Control panel	Advanced - full control & setpoint adjustment	Basic - limited control, no setpoint adjustment
Display type	Two line 32 character LCD with backlight Two 8 system status LED indicators Includes 9 meters - AC/DC volts/amps/freq Provides access to all settings	LED bar graph displays 10 system status LED indicators All settings via micro-switches on side of inverter
Optional Displays	Second advanced remote control panel PC / serial communication adapter	Advanced LCD control panel - $249 additional
Maximum control panels allowed	Two - one built-in / one remote	One only - no on/off switch on unit itself
Generator Management system	Standard - manual and automatic control	Not available
Series stacking option for 120/240 VAC	Yes	No
Parallel stacking Option for higher power	Yes	No
Suggested retail price	$2585.00 USD	$2,599.95 USD

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TOP SECRET

GUERRILLA SOLAR PROFILE: 0004

DATE: June, 1999

LOCATION: Somewhere in the USA

INSTALLER NAME: Classified

OWNER NAME: Classified

INTERTIED UTILITY: Classified

SYSTEM SIZE: 100 watts of photovoltaics; 1,500 watt wind generator.

PERCENT OF ANNUAL LOAD: 50%

TIME IN SERVICE: 2 years

NOTES: My system consists of a 100 watt Carrizo PV array that I picked up at an energy fair a few years ago. The PVs feed a small synchronous utility-intertie inverter. The wind system is a Whisper H1500 HV on a 100 foot tower. This sends 220 volt three-phase wild AC to a rebuilt Gemini utility-intertie inverter, one of the first synchronous inverters made. This inverter shuts down when the grid fails, and I have to manually restart it. It's far safer than all those Y2K backup gensets that are improperly wired and can backfeed the lines.

Our system has been up and running for about two years. Because our house is all electric, our bills are high, especially in the winter months here in the north. We use baseboard electric heat, with wood heat to supplement it in the coldest times. Our bills have been cut in half since I put in these systems. Our average winter bill used to be $100-120. Now it's only $45-65. Everyone said that this is not a good place for wind or solar. I didn't believe them and now I've proved them wrong. I am thinking of upgrading to a Whisper 3000 and maybe 1 KW of PV. Then I won't have to pay a utility bill at all!

The local power company is not at all friendly to small-scale renewables. They have ratcheting meters, so I can't actually sell power back to them. All I can do is offset our peak usage here. When our PVs and wind genny are making more than we are using, I'm giving our surplus to them. That rubs me the wrong way! But for me to go legal, they want a large disconnect and a separate meter. <u>And</u> they want to charge me a $20 <u>per month</u> meter reading fee!

I also have a 4 KW Trace inverter and a 1,000 amp-hour battery bank. I can divert the wind and solar to this standby system and go totally off-grid. If my utility rates keep going up, I might just do that...


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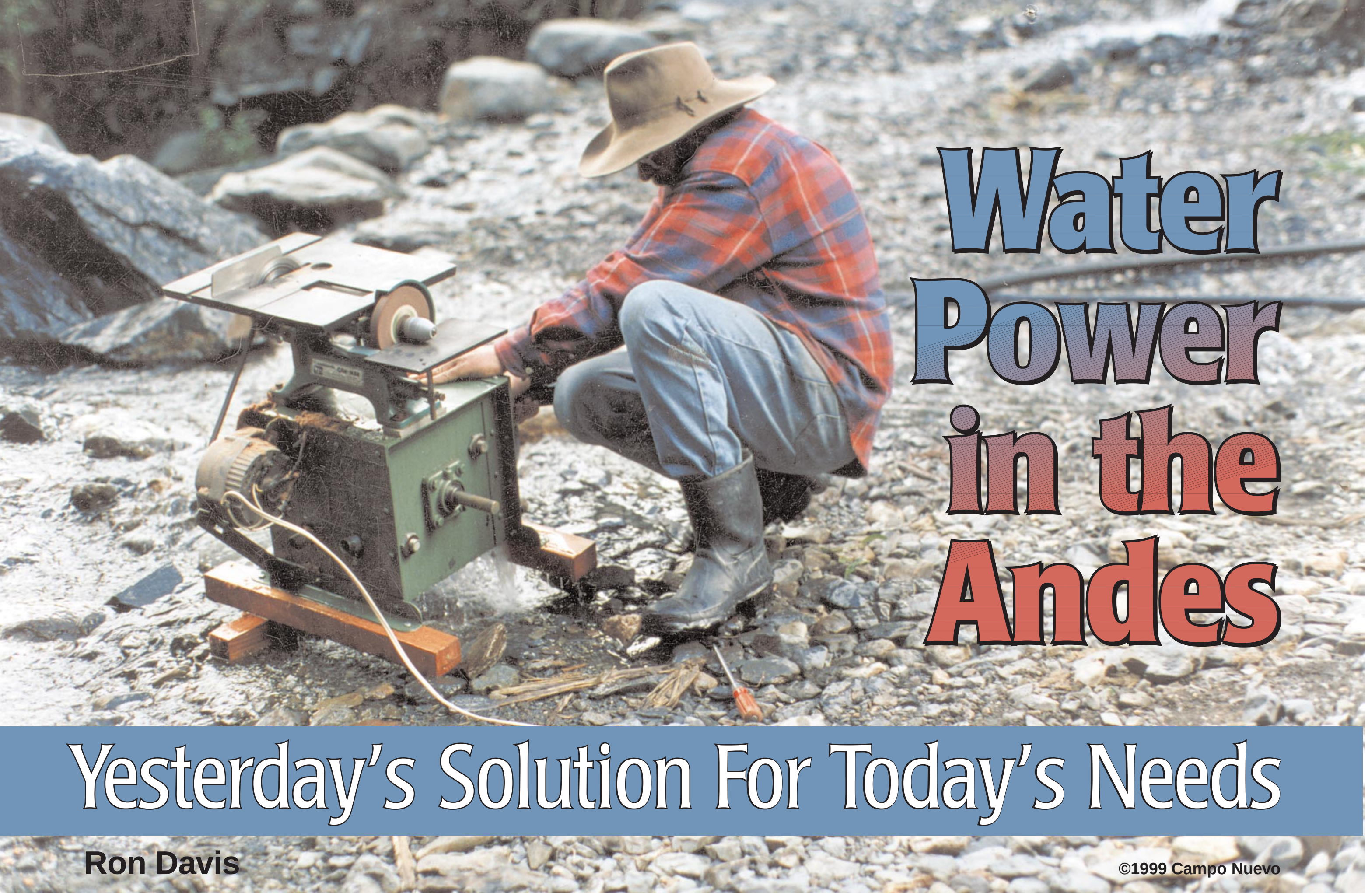


Water Power in the Andes

Yesterday's Solution For Today's Needs

Ron Davis

Ron Davis tests an early Watermotor: falling water powers a saw, grinding wheel, and alternator for electricity.

Going to work these days is always a bit of a thrill for me—often more than I care for. It means crossing a 15,000 foot (4,570 m) pass over the Bolivian Andes and snaking down a muddy one lane road carved into the face of immense cliffs. *The Most Dangerous Road in the World* was the title of an old *National Geographic* article about this spectacular route.

World's Biggest Solar Machine

Actually I'm entering the world's biggest solar energy machine—the Amazon basin. Towering glacier-topped 20,000 foot (6,100 m) peaks are clearly visible from our tropical water power demonstration site. The eastern face of the Andes so thoroughly captures the Amazon moisture that the western side—the Atacama desert—is said to be the driest place in the world. Sometimes rain only falls there a few times during an entire lifetime.

But on this side, it's just the opposite. Uncounted streams and waterfalls abound, some falling hundreds of feet directly onto the roadway! About 80 people die each year on this short section of road, since it is very narrow and slippery. Vehicles that slip off the road can simply disappear into dense vegetation a thousand feet (300 m) below. It's incredible to think that this is the only road into a tropical part of Bolivia the size of Texas.

Leaving the narrow road, it's a relief to arrive in the lovely town of Coroico at 5,500 feet (1,676 m), near our demonstration site. Green hillsides are covered with coffee, citrus, and bananas. This also happens to be the home of Bolivia's traditional coca leaf production, so the area is much affected by the U.S. "war on drugs."

Campo Nuevo—Meeting People's Needs

Over fifteen years ago, Diane Bellomy and I founded Campo Nuevo. We started our family-sized appropriate technology organization to improve lives by bringing simple technology to Bolivia's indigenous people. We teach them how to use their local natural resources for energy. We want to show people how easy it is to employ the abundant small local sources of water power to improve their lives. This can help make it possible for them to remain on their land and in their own communities.

We are working with Aymara-speaking native Americans, one of the largest and most intact indigenous cultures in the Western Hemisphere.

Notable for having withstood the Incan conquest, and later the Spaniards, the Aymaras are now succumbing to the pressures of modern global economics. Like rural people all over the "third world," they are being forced to relocate simply to survive. They usually migrate to a desolate 13,000 foot (3,960 m) suburb of La Paz, in order to compete for unskilled, low paying, and often temporary jobs.

A New-Old Solution

Although they may not realize it, what visitors to our demonstration site see is not really new. It's actually a revival of the nearly forgotten traditional use of water power. For thousands of years before the invention of centrally generated electricity, water power was employed to directly run machines, something it does very well.

What *is* new is the development of a modern low-cost turbine specifically for this purpose—a "motor" driven by water power. We call it the Watermotor. It can provide the energy to drive a variety of machines, replacing the mid-sized electric motors upon which nearly all modern production depends.

Lester Pelton, who invented the Pelton wheel, produced a variety of these water powered motors. They were in use before 1900, powering individual machines. Pelton even used one to run a sewing machine! The direct drive hydro units were replaced by electric motors after centrally produced electricity became the norm.

Few people realize how closely rural poverty is related to the lack of machines necessary for local production and services. In the third world, the power grid is usually confined to cities and large towns. Rural people still use muscle power as everyone did in the past, and they do without electric lights. The need to generate cash to buy anything they don't produce themselves causes a focus on cash crops. This further reduces their self-sufficiency, encouraging a downward spiral towards dependency on a system that cannot be depended upon!

Demo Site

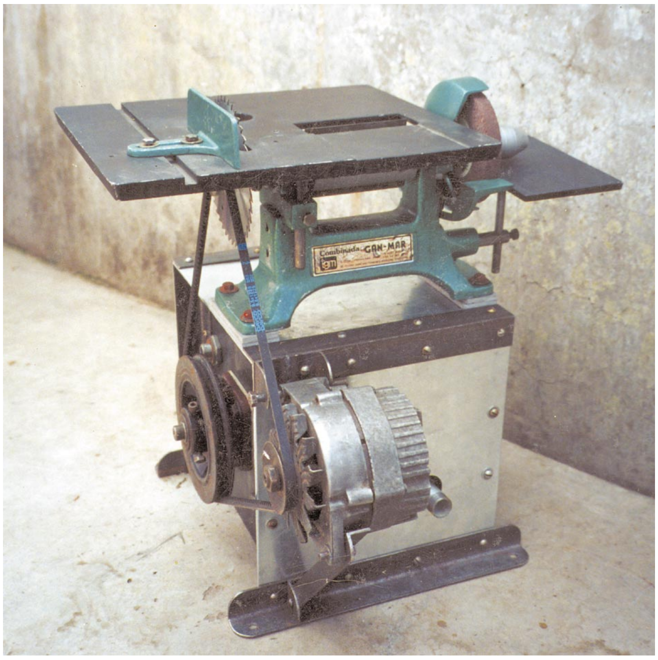
Water power is nature's most concentrated form of solar energy, and by far the easiest to convert into usable mechanical power. At our new Campo Nuevo demonstration site, we are featuring practical machines, directly powered by water. There are woodworking tools, air compressors, and water-powered water pumps. We also run an auto alternator to charge batteries and provide lighting. This can be switched on when mechanical power is not being used, and is driven by the same belt drive that powers the tools.

The main attraction at our site is a Watermotor driving a small multipurpose woodworking unit. The machine is suitable for producing doors, window frames, and furniture—necessities usually purchased from the city. It processes locally grown timber instead of wood carried up from the Amazon forest.

Campo Nuevo assistant, Iran, rips a board.

The Watermotor at our demonstration site is provided with power from a water source located 65 feet (19.8 m) above the machine by four 170 foot long (52 m) 1 1/2 inch (38 mm) polyethylene pipes. At the heart of our turbine are two Energy Systems & Design plastic mini-Pelton wheels, mounted on a single shaft and driven by two water jets each. With a flow of 82 gallons (310 l) per minute, we get power similar to a 3/4 HP electric

The first Watermotor—the start of a revolution.



Plumbed to the power and ready to rip.

motor, at about 1,450 rpm. Unlike an electric motor, the Watermotor costs nothing to operate and can't be burned out by hard use.

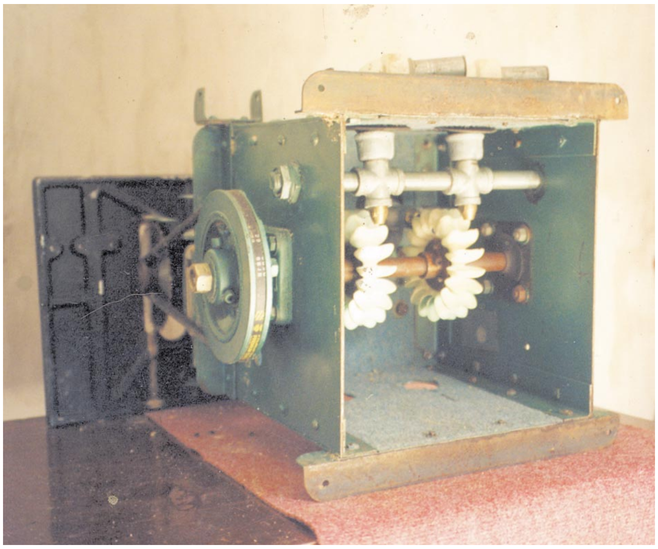
It's Not Easy

Not much of this area is served by roads or the power grid. The U.S. owned (and U.S. priced) power generating system has little incentive to provide long distance lines to a widely scattered and typically impoverished rural population. Water power is the sole available practical source of energy to run machines. There is not a good wind resource in the mountain valleys and PV is just not economical, compared to the abundant water power here.

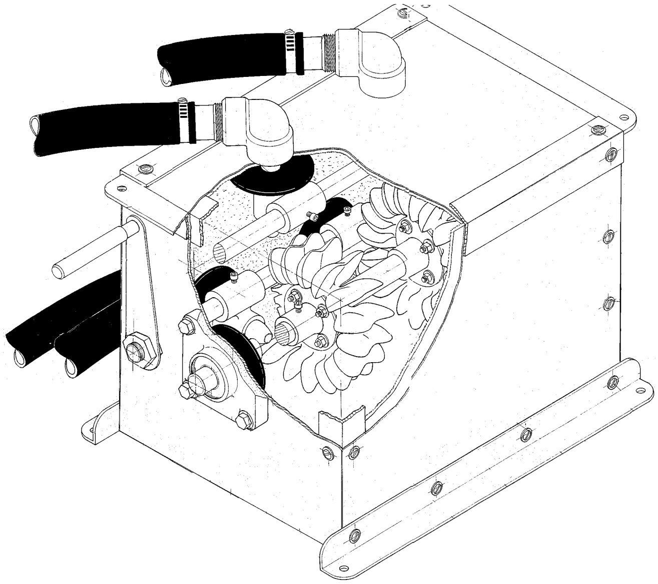
There are major obstacles to the introduction of unfamiliar technology to an indigenous population that has traditionally used no machines of any kind. These people have little money to invest in anything that does not promise a practical return. In addition, the Aymaras are unlikely to be reached by advertising in the city newspapers. This is why we felt that a local demonstration site was necessary.

Other problems are encountered when machines, however useful, need to be professionally installed, maintained, or repaired. Outside the city, such services are frequently unreliable, hard to come by, and expensive when available.

The Watermotor on its side with twin turbines exposed.



Cutaway View of the Watermotor



Keep It Simple

In order to overcome these obstacles, we designed the Watermotor to be user installed, maintained, and repaired. Because it is locally produced from common materials, all parts can be easily replaced. Only the Pelton wheels need to be obtained from other than local sources. A Watermotor can be made with hand tools and a drill press, though some welding is required. Most builders will find it convenient to have the hubs which connect the Pelton wheels to the shaft made by a local machine shop.

The efficiency of direct drive water power is a big advantage. A surprisingly small amount of water falling a short distance can produce the 0.5 to 3.5 HP of mechanical power required by most common machines. This means that many potential water power sites are available, and a minimum of civil engineering is required. Water is carried to the turbine by low cost, easily transportable plastic pipes. Rigid large diameter penstocks which require skilled installation are not necessary.

Other projects by Campo Nuevo include ferro-cement water storage tanks, ram pumps, hand powered water pumps, electric and treadle spinning machines, and adobe brick and plastic greenhouses.

The Watermotor itself is very simple to build, operate, and maintain. It functions efficiently in a variety of water power situations. By merely experimenting with easily changed water jets of different sizes, it is possible to vary maximum power output. This also allows the turbine to maintain efficient output over seasonal water flow variations. Control handles connected to the jets are used to divert water flow away from the Pelton wheels, cutting power.

Power Output

Regarding output and efficiency, you can determine how much energy you could get from a particular water power source by using this formula:

$$HP = H \times F \times E \times 0.18 \div 746$$

where HP is horsepower, H is total head (fall) in feet, F is flow in gallons per minute, and E is efficiency in percent. For the metric equivalent to this formula, see pages 42 and 43 in this issue.

Several things need to be considered along with this formula. Pelton wheels are usually about 75 percent efficient. There will always be some pressure loss due to friction in the water supply pipes. Your local supplier should be able to help calculate this for different products. Tables for pressure loss in pipes of various sizes can also be found in alternative energy catalogues.

The power output of the Watermotor depends on the fall and the amount of water used to run it. Here are some examples of other possible installations and the energy output that they would produce:

• A 100 foot (30 m) fall and 110 gallons (416 l) per minute would produce 2 HP at 2,050 rpm.

• A 150 foot (46 m) fall and 184 gallons (697 l) per minute would produce 5 HP at 2,550 rpm.

The Basics

The Watermotor can be used to drive most stationary machines normally driven by an externally-mounted electric motor or small gasoline engine in the 0.5 to 3.5 horsepower range. Power output can also be increased by simply lengthening the housing to accommodate more Pelton wheels, without basic design change.

Machines are driven by standard belts and mounted directly on or beside the turbine housing. The shaft between the Watermotor and the tool is 7/8 inch (22 mm), and the housing is about 12 by 12 by 14 inches (30 x 30 x 36 cm). The turbine must be mounted to accommodate the outflow without having water back up. We use a cement box as a tailrace, with a 4 inch (10 cm) drain pipe which returns the water to the stream.

Make the Comparison

How does the Watermotor stack up against the competition? I asked a couple of RE experts to give me the rough cost of a wind or PV system capable of producing 2 1/2 HP of mechanical energy 24 hours a day, including installation in rural Bolivia and technical expertise for maintenance and repair.

Richard Perez of *Home Power* said, "Well, the PVs alone will cost about US$35,000. And the requirement for 24 hour power at that level means a very large battery bank which will bring the system cost up to around US$70,000. And we still need to add small stuff like racks, inverter, and controls. Overall, I'd say about US$80,000. It really points out how cheap hydro is."

North American wind power guru Mick Sagrillo said, "My guess, using off the shelf equipment, would be that you'd need a 10 KW Bergey Excel. While it's larger than what's needed, it's cheaper than putting up several smaller turbines. The cost for both genny and controls is about US$20,000, less tower, wiring, batteries, and balance of systems components. Total system cost would be roughly US$35,000. The one message I always deliver at my wind power workshops is that if anyone has a good hydro site, they're in the wrong workshop. While wind is cheaper than PV, it's no comparison for a hydro site with a 100 percent capacity factor."

Now, this is not a scientific comparison, and these are admittedly rough figures. But the Watermotor can produce 2 1/2 HP continuously—with a system cost of less than US$2,000. It's user installable and maintainable (two lubrication points), and easily repairable. It has only one moving part, can be locally produced in a small shop, and is immune to damage from hard use. Also consider that PV and wind equipment are imported, and that there's a good chance of damage from misuse or poor maintenance.

Watermotor type designs were abandoned about l00 years ago in the developed world in favor of electric motors. To the best of my knowledge, there are no machines equivalent to the Watermotor being produced today. Generally, very few products, no matter how useful, are produced with the aim of promoting self-sufficiency among the world's rural poor.

Water Power to the People

The best advertisement for our water driven machines is for them to be seen hard at work by the many people passing the demo site daily. Woodworking machines in particular have a substantial per-hour cash value. Because the Watermotor is immune to damage from hard use, it is suitable to rent or lease. At current rates, the entire cost of a Watermotor installation should be recovered in only a few months.

We expect visitors to our demonstration site to have their own ideas about how they can use the Watermotor. The experience gained at this site will provide us with knowledge and incentive to build similar sites in other parts of Bolivia. Plans are available—contact us for more information about building and using the Watermotor.

While Bolivia is especially rich in water power resources, many other parts of the world have similar conditions, and similar needs. We would like to see this clean, self-renewing, easy to use natural resource made available to all.

Access

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TOP SECRET

GUERRILLA SOLAR PROFILE: 0005

DATE: June, 1999

LOCATION: Somewhere in the USA

INSTALLER NAME: Classified

OWNER NAME: Classified

INTERTIED UTILITY: Classified

SYSTEM SIZE: 500 watts of photovoltaics.

PERCENT OF ANNUAL LOAD: 50%

TIME IN SERVICE: 1 year

NOTES: My system is based on a Trace SW2512 inverter, as you can see from the photo. I have eight Siemens PV panels producing over 40 amps. My battery pack consists of eight Trojan L-16s. This is my base system--I plan to expand when needed.

Right now, I use solar to power my TVs, stereos, and computers, plus several lights, including exterior lighting. I've been living in my custom 5,400 square foot home for about a year now, and the system is great. Even with this large house, my power bill last month was only $28. Before I put the system in last year, my bill was about $60 a month.

I'm also using a Stargate home automation system. The Stargate uses X-10 technology, and sends its signal through the existing electrical wiring in the house. I need to have the inverter in sync with the sine wave from the grid to reach throughout the house. The inverter must be in sell mode to do this.

This automation system is also an energy saver. Lights and other loads never get left on unnecessarily. I'm working on a summer home up north and I'll set it up so I can control the heating automatically from down here.

I have a strong desire to be independent. I want to give back what I can in terms of energy. I built this custom home and I can control the various independent systems. I'd like to have one of your T-shirts to proudly say I'm a Solar Guerrilla.

Will Your Utility Interact With You?

Utility Interactive Inverter Safety

Joe Schwartz

Take a look at today's market for utility interactive (UI) renewable energy systems. In the U.S. alone, utility interactive inverters capable of safely placing clean, independently-produced electricity onto your local utility grid are being sold and installed by the thousands. The grid intertied RE market is booming as Americans spend big money on state of the art equipment. In most cases, people are doing so without any hope that their system will ever provide a monetary payback. What's their motivation?

For one thing, they want a cleaner environment and they are willing to pay for it. And with the addition of batteries, a UI system takes on a greatly expanded role as an uninterruptible power supply (UPS) for both residences and businesses. Homeowners now have the ability to back up critical household loads like well pumps, furnace blowers, freezers, computers, and lighting. Today's business environment absolutely requires an uninterruptible and high quality source of power, since information transfer is expected to be seamless.

Think about it. Virtually every hospital, bank, and large business has invested in a UPS. The utilities' lack of confidence in their ability to deliver continuous high quality power is obvious as we watch them recommend surge suppressors and UPSs for customers with home computers.

UI inverters give us the ability to safely place energy from the sun, wind, and water onto the utility grid and share it with our neighbors. UI inverters give our homes and businesses a source of electricity when the grid fails. UI inverters give some utilities a headache.

Who's Above The Law?

Utility response to small-scale generation from renewable energy has ranged from caution to downright foot dragging. If you're living on-grid, you probably already know that your local utility has what amounts to a monopoly on the electricity you're buying. Don't like the service? Tough.

Americans have had to resort to legislation in order to liberate clean energy from the grasp of repressive utilities. Currently, twenty-seven U.S. states have enacted net metering legislation, which forces utilities to pay their customers a fair price for independently produced renewable energy. However, even in states where net metering is law, many local utilities are making implementation so difficult that the laws are meaningless. Citing safety, reluctant utilities are skirting legislation by requiring UI customers to have excessive insurance policies and expensive, redundant safety equipment.

It doesn't even stop there. This past year, utilities in both Maine and Iowa challenged state net metering laws, attempting to have them repealed outright. Fortunately, clean energy supporters handily defeated utility interests in both cases (see Bill Lord's article in *HP65).* Remember, as a utility customer in a net metering state, you are simply attempting to exercise your legal right to put clean electricity onto the local utility grid, and receive a fair payment for your investment.

Are You Above The Law?

Take a look at today's market for utility interactive renewable energy systems. In the twenty-six states without net metering legislation, you'll begin to see RE systems being installed without the benefit of statewide legislation or even the approval of utilities. Take another look and you'll see that the number of installed UI systems in the U.S. may have just doubled.

Regardless of the local utility's position, Americans are purchasing and installing UI inverters and renewable charging sources because it's the right thing to do. If you come up against a stubborn utility, you just might find yourself quietly hitting the "sell" button on your inverter. The result? De facto net metering without jumping through hoop one. It's painfully obvious that the technology of UI power systems—and the human ingenuity behind them—is outdistancing ineffective regulation and unwilling utilities.

While most *Home Power* readers give a quiet nod to unauthorized or guerrilla RE systems, disregarding

obstructionistic utilities is an uncomfortable position for some. What's their big issue? The safety of utility line workers, without exception.

Utility Interactive Inverters
Modern synchronous inverter technology allows for safe and efficient home-based utility-interactive generation systems. These inverters are capable of synchronizing the frequency of their AC output to the waveform of the utility grid. The popular Trace SW series inverters, manufactured in Arlington, Washington, have revolutionized the grid intertie market and represent the majority of UI inverters currently installed in the U.S.

Trace sine wave inverters are available for both battery-based UPS and battery-less applications. Battery-based UI units are available with outputs of 2,500, 4,000, and 5,500 VA (volt-amperes) at either 120 or 240 VAC/60 Hz. Export models are also available with 230 VAC/50 Hz outputs. Battery-less UI units offer outputs of 4,000 and 5,500 VA at either 120 or 240 VAC/60 Hz. Export models are also available for the battery-less UI units. If power demands are higher than the rated output of a single inverter, two battery-based units can be operated in series with the addition of a stacking interface cable. This configuration effectively doubles inverter output.

Multiple inverters can be used for outputs of up to 30 KW. Can't afford 30 KW of PV right out of the gate? On the other end of the spectrum, Trace offers small synchronous inverters with a rated output of 100 VA. The MicroSine inverter is available with 120 or 240 VAC/60 Hz output. Again, export models are available. This synchronous inverter is designed for battery-less installations using one 24 VDC PV or two 12 VDC PVs.

Advanced Energy Systems (AES) of Wilton, New Hampshire, also manufacturers a synchronous, module-integrated inverter with a rated output of 250 VA. In addition, AES is currently manufacturing the conveniently sized GC-1000 UI inverter, with a rated output of 1,000 VA. Both of these AES inverters are designed for battery-less, UI applications.

All of these inverters have been tested and approved to meet the safety standards established by Underwriters Laboratories (UL). These listed products are certified to perform safely, as advertised. Because the Trace SW series inverters currently make up the majority of installed UI inverters in the U.S., their safety features deserve a closer look.

Safety Break
The protective systems of the Trace SW series inverters are exceptional. These systems are designed to protect utility personnel and both private and utility owned power generation and transmission hardware. The protective features address all situations where disconnecting a UI inverter from a failed utility grid is essential, including open circuit, short circuit, and islanding conditions.

The safety features specified by the manufacturer have been approved by all utilities who have undertaken testing of the inverters. No shortcomings in the units' protective circuity have been documented. In fact, in some applications, poor utility power quality has actually limited some customers from using their SW inverter in UI mode. The inverter's preset power quality parameters will not allow the unit to become synchronous with the utility if grid voltage varies +/-10 percent or frequency varies +/-2 Hz. To meet proposed IEEE (Institute of Electrical & Electronic Engineers) standards, an upcoming software revision will preset this frequency window at +/-0.5 Hz.

Open and Short Circuits
Wind and ice storms take down power lines across the U.S. quite frequently. This typically results in either an open circuit, if the downed lines are cut, or a short circuit, if hot and neutral wires come into contact. In an open circuit condition, the Trace SW series inverter will disconnect from the utility grid within one second of the loss of grid power. If a short circuit occurs on the grid, the inverter will reach its overcurrent limit and disconnect its output from the utility in under four milliseconds.

It's important to note that the inverter does not arbitrarily attempt to re-synchronize with the grid after a separation from the utility has occurred. Before reconnecting to the utility grid, the inverter monitors for excessive variations in either the frequency or voltage of the grid for eight seconds. If grid power quality is within specified parameters, the inverter's output will synchronize its waveform with the grid for an additional eight seconds. During this period, the inverter's microprocessor will continually monitor for unacceptable voltage and frequency variations, and phase angle differences greater than two degrees. Only after the grid is determined to be stable will the inverter open an internal relay and resume parallel operation with the utility.

Islanding
A slightly more complex safety concern related to UI inverter use is a condition called islanding. This refers to a fragmented utility grid where a UI inverter or engine generator could possibly energize the lines within this island. Imagine, for example, that the power lines were cut in two places, leaving you and your neighbor's houses connected to each other, but not to the grid. Your UI inverter or engine generator could theoretically energize the lines between the two houses.

Islanding first became an issue when generators were incorrectly installed and backfed an islanded utility grid. Without the addition of advanced power conditioning equipment, most engine generators lack the control logic incorporated into all UI inverters, and will not disconnect from an islanded utility grid. Unfortunately, irresponsible generator use has both injured and killed utility workers. It has also made many utilities hesitant or straight out unwilling to allow any non-utility generated electricity onto the grid.

Trace has eliminated the possibility of their UI inverters causing an islanded condition by incorporating an active islanding detection circuit. This circuit relies on a zero point crossing strategy to ensure disconnection from an islanded utility grid. The circuit monitors the waveform of the utility grid every time the sine wave crosses the zero point. That's approximately once every 16 milliseconds. If a loss of source is detected, the inverter is offline within one second.

This hypothetical islanding situation can be stretched even further. Say your neighbor fires up an improperly installed engine generator and backfeeds the same fragmented grid. Your inverter would initially attempt to sync up with the output of the generator as if it were the utility grid. In this instance, the inverter relies on its over/under frequency and voltage circuits. Again, if the frequency varies +/-2 Hz, the inverter is offline in under one second. If the inverter senses +/-10 percent variation in voltage, it is offline in under one second.

Trace Engineering's literature states that "since the inverter is locked onto the frequency of the islanded utility grid, the frequency of the system will drift out of regulation in a short amount of time during an islanding condition." The conclusion is that the islanded system will be overloaded in terms of generator/inverter capacity and that the frequency, voltage, or both will drop below spec, causing the inverter to disconnect from the islanded grid. But let's be clear—the inappropriate use of the engine/generator is the cause of this situation and the owner of that system should be held responsible.

As an aside, Trace SW inverters have the capability of auto starting engine generators based on either preset voltage or time parameters. The inverter's control circuitry will not allow a connected generator to attempt to operate in parallel with the utility.

Additional Safety Features

Concerned *Home Power* readers have argued, "What if the inverter's protective systems fail and injure a line worker?" The protection circuitry of each Trace SW inverter is tested and certified before the unit is shipped from the factory. However, no equipment can be guaranteed never to fail, and Trace Engineering is aware of this. In addition to the safety functions of the inverter's main processor, five additional dedicated safety circuits continuously monitor the main processor. In the unlikely but not impossible event of a main processor failure, these circuits will immediately shut down the inverter and will not allow it to restart.

You might ask, "What if all five of these protective circuits fail?" To threaten a line worker's safety, all of the inverter's redundant safety features would need to fail simultaneously. With thousands of UI inverters installed, this type of catastrophic failure has never occurred. In addition, this undocumented failure would need to occur while the inverter was feeding electricity onto the grid, within 16 milliseconds of a grid failure, and the inverter would need to synchronize with a utility grid that doesn't even exist. Finally, in order to be injured, utility line workers would have to ignore the same protocol they rely on every day they are in the field (assume that it's hot, and ground all potentially energized conductors). Remember, utility workers are trained professionals and routinely work under hazardous conditions.

Demand Clean Energy

Utilities are responsible for the well-being of their line workers and they need to be thorough when evaluating the safety features of unfamiliar equipment. Our obvious first step is to educate inexperienced utilities regarding the power quality and redundant safety features modern synchronous inverters incorporate. If a given utility is still reluctant to approve an installation for reasons of safety, then their motivation is suspect.

What else could possibly motivate them? Try money and control. Utilities despise the thought of having their rates legislated, but then they're the ones that make this a necessity in the first place. Many utilities will also assert that the transmission of your renewable energy amounts to a subsidy and that it is unfair to expect the utility or its entire rate base to bear this cost. You can point out that they don't seem too concerned about the entire rate base breathing their pollution.

And don't fail to mention that U.S. utilities have been subsidized from day one. Federal subsidies fund the construction of their dams and transmission lines. U.S. citizens subsidize the utilities with our tax dollars as we undertake the nearly impossible task of revitalizing dead salmon runs and cleaning up their failed nukes. All we ask is that the utilities place our renewable energy onto the grid and pay us a fair price for our investment. It sure doesn't seem like too much to ask.

And if you do ask, and your local utility plays obstructionist, you will find yourself facing the same decision hundreds of other Americans continue to face.

How important is clean, renewable energy, and does the utility have a responsibility to distribute it? In a perfect world, the utilities would welcome our renewable energy onto the grid and there would be no need for unapproved, guerrilla RE systems. The funny thing is that the people the utilities are so concerned about are the very ones trying to make the world a little more perfect.

Utility Interactive Checklist

Anyone interested in installing a utility interactive RE system should have a thorough understanding of what makes a given system safe. Ask your equipment supplier any specific questions you may have. If you come up short, try the equipment manufacturer or your local utility. If you still have any doubts, then hire a local RE dealer to install the system for you. Here's a checklist for anyone planning to install a UI system.

• All products used in your system should carry a UL or equivalent listing. This ensures that the gear that you, your neighbors, and utility line workers are relying on has been certified to be safe.

• Your system should be installed to meet NEC code. This includes appropriate wire sizing, fusing, disconnects, and equipment accessibility and clearance. Your system should also be inspected by your local electrical inspector. This inspector is concerned primarily with fire safety and typically does not operate in conjunction with utility personnel.

• Above and beyond the UL certified safety capabilities built into utility interactive inverters, both the NEC and utilities typically require either a manual disconnect or a satisfactory visible open point at the location of interconnection. This establishes a means for utility workers to disconnect all on-site sources of power generation. Accepted options range from utility workers simply removing the meter from the meter base and capping it off, to providing a separate, lockable disconnect that only utility personnel can access.

• The means of disconnect should be clearly labeled as such, for example "Solar Electric System Disconnect."

• An attempt should be made to get approval for your UI system from your local utility. The more aware and educated the utilities are regarding the use of UI inverters, the more commonplace they will become. Currently, twenty-four states offer net metering for RE systems. But beware—local utilities can make approval of your system virtually impossible even with net metering legislation in place. This scenario forces customers to either go guerrilla or worse yet, abandon their project altogether.

Access

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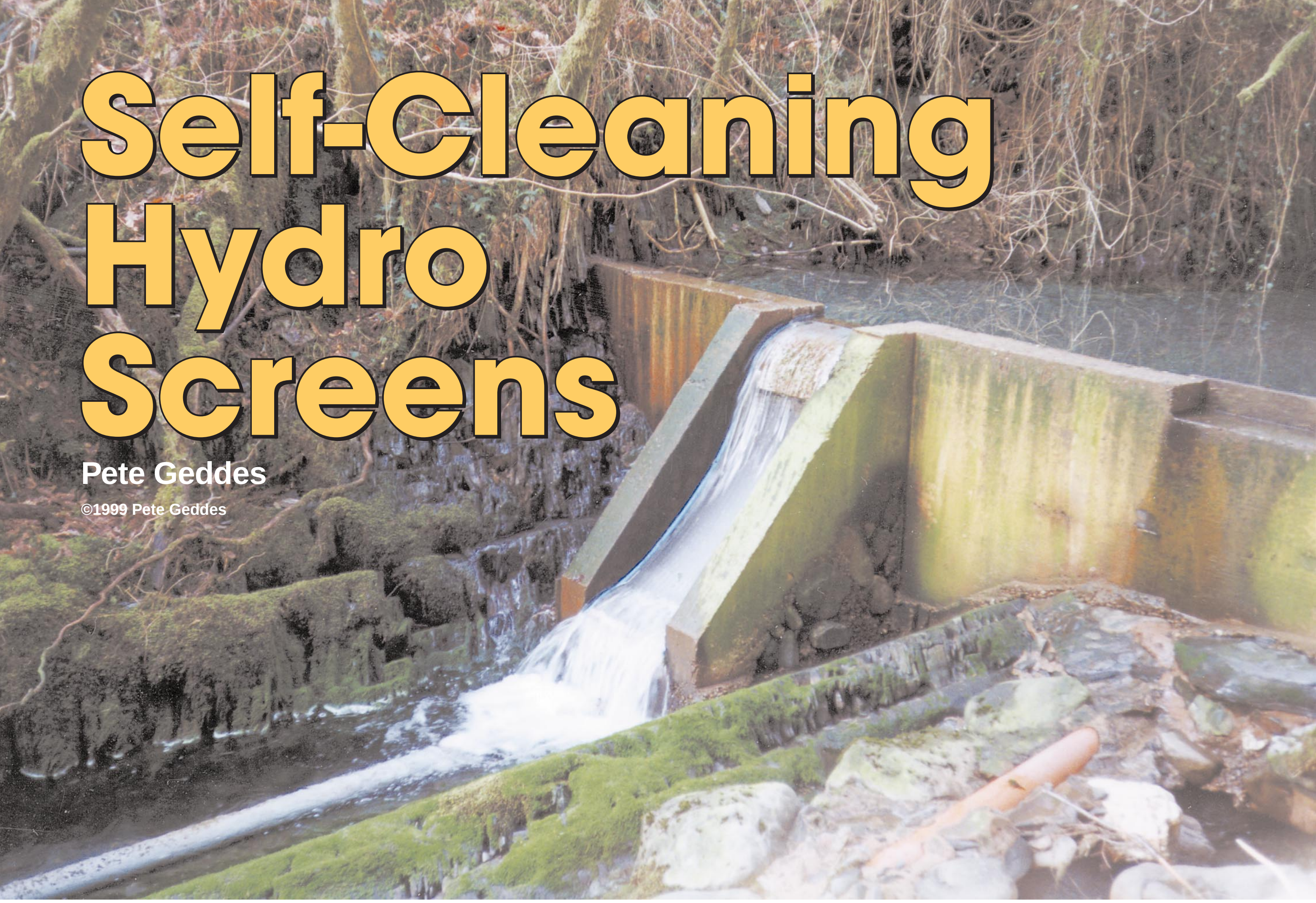
MATRIX

full page
four color on negatives

this is page 63

Self-Cleaning Hydro Screens

Pete Geddes



A Coanda effect screen on the intake at Nick Mills' site saves lots of long cold walks during the night to clean out debris.

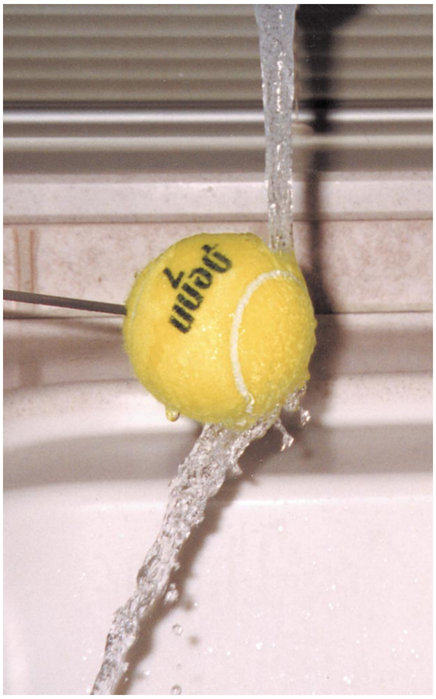
Run-of-river microhydro systems use stream water as it's available, with no significant water storage. Most of these systems use fixed trash racks for diverting marine life and debris at the intake point. Although the racks themselves are not expensive, their maintenance and periodic cleaning, whether manual or powered, can cause real problems in debris-laden streams.

Common problems include intermittent power output caused by blocked screens, pipes, or jets; turbine damage caused by continuous abrasion or sudden impact; or even burst pipes caused by sudden pressure rise (surge) as a result of a completely blocked jet.

The Aqua Shear screen can avoid many of these problems. This innovative intake screen was developed in the USA, and is proving popular internationally. The screen protects fish, removes debris and silt, and requires no manual cleaning, maintenance, or external power source.

Coanda Effect

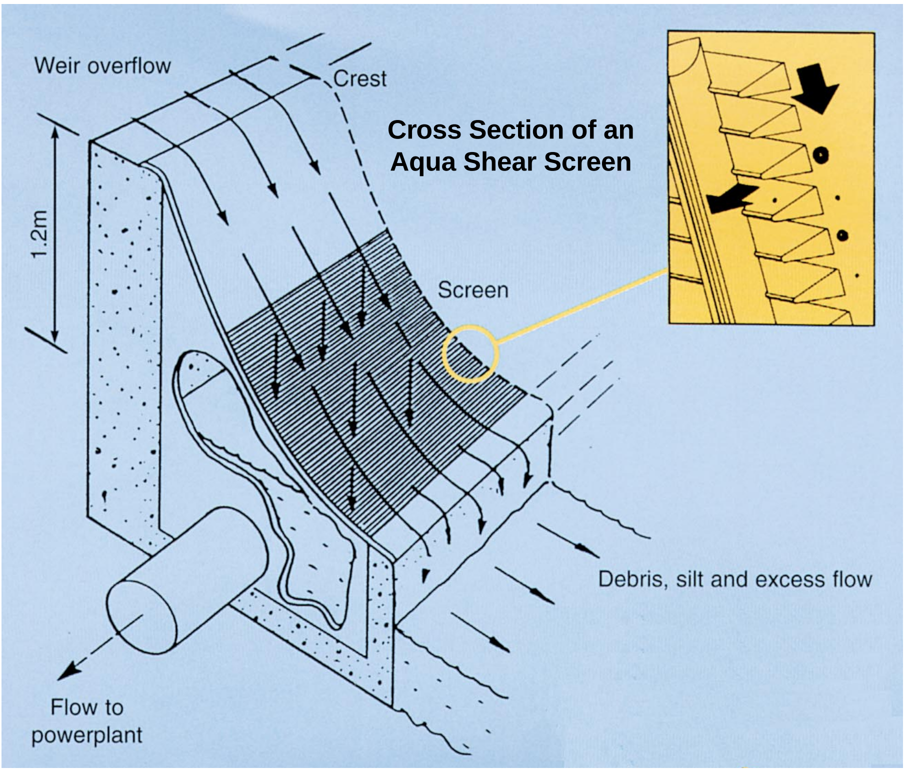
The Coanda effect is named after Henri-Marie Coanda, who first identified the effect in 1910. It describes the tendency of fluids to follow a surface. Stick your finger under a tap and notice how the water runs along the underside of it; this is an example of the Coanda effect. Today the effect is exploited in the design of jet engines and turbo-charged internal combustion engines.



The Coanda effect is demonstrated by the water adhering to the surface of the tennis ball.

This tendency of fluids to follow a surface is utilized in the Aqua Shear screen by the means of a row of horizontal "wedge wire" bars, arranged with a spacing of 1 mm or less, perpendicular to the flow. The bars are tilted up about five degrees relative to the slope of the screen and "shear" a part of the flow passing over the screen.

The flow is separated by this shearing action and the Coanda effect, which pulls the water down along the vertical surfaces of the bars. Clean water passes down through the screen, drawn in at the rate of 102 liters per second per square meter of screen (2.5 U.S. gps/ft^2). Water containing fish, sediment, and debris passes over the screen to rejoin the watercourse below the weir.



From Coal to Hydro

The screen was originally developed in 1955 as a simple apparatus for the wet screening of coal slurries. Some years later, it was found to be ideally suited as a maintenance-free screen for hydro systems with high silt loads or debris problems.

In the USA, the screens have been in use since the early 1980s, installed on fifteen systems of up to 11.9 MW capacity and up to 7 cubic metres per second (1,849 U.S. gps) flow. In Europe, the screen is manufactured under license by Dulas Ltd. in the UK, and is installed in eight systems ranging from 0.5 KW to 300 KW.

Fish and other forms of aquatic life are washed over the surface instead of being sucked through or onto the screen, as in a normal hydro installation. As a result, the Coanda screen has been well received by environmental and wildlife organizations, including the U.S. Fish and Wildlife Service.

The screen's performance has been proven under severe conditions of freezing and floods. The screens resist impact damage from tree limbs and boulders during floods, due to their steep angle away from the flow and the high degree of frame rigidity. For widths of more than 0.5 metres (1.6 ft), an integrated stainless steel supporting frame is welded to the screen to allow several sections to be bolted together side by side.

Screen Construction

The Aqua Shear screen is fabricated to high tolerances from stainless steel. In addition to its self-cleaning property, the screen has a desilting function. Ninety percent of 0.5 mm suspended silt particles and all 1 mm particles are screened out of the flow to the turbines, eliminating a desilting tank in many systems. Screen spacing is engineered for a certain size, which can be 0.2 to 1 mm, as chosen by the client.

The associated concrete construction is straightforward. The frame is simply bolted to horizontal and vertical concrete faces. There is a loss of about one metre (3 ft) of head from the weir top to the intake water level, which can be reduced as low as 0.64 metres (2 ft) for low head systems.

Another possibility currently being investigated is to mount a screen in a box attached to the diversion outlet. Water is piped to the box, where it is screened, with the debris and overflow returning to the stream. This alternative eliminates the need for a large and costly diversion structure, while still providing a relatively maintenance-free screened diversion.

Vulnerability

Compared to the heavy bars typical in conventional intakes, the fine wire of the Aqua Shear screens might seem to be vulnerable to rock damage. But the screen is angled steeply away from the direction of water flow, and has heavy framing and support rods. These design features protect the screens from boulders and tree limbs in almost all cases. To give one example, severe flooding on the Bear Creek 3 MW site in northern

The 4 KW system in Wales after several months without any cleaning, with no detrimental leaf build-up.

California in 1986 put the entire diversion under three metres (10 ft) of water, but the intake continued to perform normally.

Freezing

With a lateral intake, the conventional approach is to submerge the screen, use low conductivity materials or coatings, and encourage ice to form at the surface by keeping velocities low. These techniques seem unnecessary with Coanda screens used down to air temperatures of -20° C (-4° F), where there is evidence of good performance. A system on Blueford Creek in California, for example, has data for one week at -20° C with no reported problems. The diversion at Beaver City, Utah has operated successfully at air temperatures as low as -30° C (-22° F).

The Competition

Some small hydro screens have just a short length of large diameter pipe with holes or slits cut in it. These can be partially dammed around to keep them submerged. This type of screen has problems—vulnerability to rock damage and gradual blocking of the screen holes. Hole size is limited by the turbine jet nozzle size. The screen must not allow particles larger than the nozzle to pass through, or else the jet is liable to block. If this happens suddenly, the pipe may burst due to surge.

The Tyrolean style weir is a more expensive but partially self-cleaning intake. This screen is angled away from the flow like the Aqua Shear, so it is less susceptible to blockage and boulder damage. Its self-cleaning effects are limited, however, so it is still more vulnerable to blockage than the Aqua Shear. Complicated concrete construction can result in this intake design costing more than an Aqua Shear intake.

A last type of intake screen is the automatic screen cleaner, or "screener." In this type of system, a hydraulically operated brush or scraper periodically brushes the screen to remove debris. These are becoming more popular, despite being expensive and requiring power. Due to the relatively high power demand, these screen cleaners are not considered appropriate for small domestic systems.

In contrast to these common intake arangements, the Coanda effect screens work exceptionally well. Three examples of hydro sites utilizing the Aqua Shear intakes follow.

4 KW System: Holiday Cottage in Wales

A full monitoring programme was completed by Dulas Ltd. in 1996 at a 4 KW system in a wooded catchment (watershed) in the mid-Wales region. The goal was to verify capacity, self-cleaning, wear, reliability, and anything that might decrease the system's capacity over time, such as algae growth or freezing. The system supplies mains power to a nearby holiday cottage, with storage heaters and dehumidifiers connected as dump loads. The loads run continuously during the long spells when the cottage is empty.

During the eight month monitoring period, the Aqua Shear screen worked perfectly, with no cleaning necessary. Silt exclusion was excellent, with 97 percent of silt removed, above and below 0.5 mm size. The cottage no longer suffers from dampness or mustiness when the owners turn up for a weekend, and they get clean, quiet electricity for free. A self-cleaning screen is ideal for this kind of system where a dwelling is unoccupied for long periods.

1.75 KW System: Nant-y-Garren, Gwynedd, Wales

An old secondhand 1.75 KW Gilkes Turgo turbine and Newage generator supply Nick Mills' only electricity. The intake is remote to the house, being one mile (1.6 km) up the road, and down a steep 50 foot (15 m) gorge. The catchment area is steep and flashy (prone to flash floods), with lots of leaves every fall.

Over a period of five years, Nick tried a number of devices to reduce blockages. Watching the TV fade out and having to go out to clean the screen two or three times a week in the winter in the cold rain convinced him to do something serious. He decided it was a choice between noisy, expensive diesel power and sorting out his hydro intake.

A new intake structure with an Aqua Shear screen completely eliminated Nick's problems, and made the intake system 100 percent reliable. He has not had to visit the intake since installing the screen in 1996!

300 KW System: Swiss Alps

Entec, a Swiss renewable energy consultancy, recently completed an investigation on a 300 KW system in the high mountains of the Swiss Alps, monitoring a difficult intake. The new Aqua Shear screen replaced the original Tyrolean (drop type) intake. For thirteen months, the performance was monitored by various means including the use of an automatic camera, providing a still photograph every 24 hours.

After the new screen was fitted, the system did not shut down once due to a silted or clogged intake. Removal of debris and leaves was found to be excellent; the screen was 100 percent self-cleaning. It performed normally under freezing conditions down to -20° C (-4° F) air temperature. Freezing is prevented in very low flows by using stoplogs to direct the flow over the centre of the screen. Sand rejection was considered particularly good; 94 percent of particles greater than 0.5 mm were rejected. This investigation concluded that the screen was economically and ecologically sound for systems with sufficient head.

Maintenance-Free Intake

The Aqua Shear screen offers significant advantages in a wide range of small hydro applications as the trend to unattended systems increases. European prices start at UK£350 (about US$564), for a 7 liter per second (0.25 cf/s) capacity screen. They can be retrofitted to existing difficult sites, but are more economical when included in a new system.

The range of applications includes small hydro intakes, filtering water for agricultural irrigation, and pretreatment for municipal and industrial water supplies. Aqua Shear screens offer maintenance-free intake management. They reduce wear on turbines and completely eliminate potential blockage.

Access

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The Rises & Falls of Henri-Marie Coanda, Air & Space Magazine, Aug./Sept. 1989

Y2K Prescription

Advice from Renewable Energy Dealers & Distributors

Allan Sindelar & Ian Woofenden

Renewable energy dealers and distributors are receiving lots of inquiries about standby electrical power systems to provide power and water in the event of an extended utility outage on January 1, 2000. Some people are asking about photovoltaic (solar electric, or PV), wind, and microhydro power options. Others ask about using a portable gasoline or propane fueled generator as a backup power solution. Others want to know about battery banks and inverter/chargers.

Predictions of what will occur on January 1, 2000 range from a few minor inconveniences to the total collapse of society. Unlike a hurricane, tornado, or earthquake, we have a date circled on our calendars. But no one can accurately predict the extent of disruption, or if there will even be one.

How can you prepare for a power outage and the problems it would cause? Unfortunately, the solution is not simple. A PV system that can provide abundant electricity for a typical off-grid home will not run a conventional home.

Designed for Efficiency

Off-grid homes are designed and built with solar electricity in mind. Lighting, appliances, electronics, and wiring are all selected and installed to make each watt-hour of electricity do as much work as possible. Tasks such as cooking, clothes drying, water heating, and space heating are shifted to natural gas, propane, wood, or solar heat. Done well, the result is a home that is bright, warm, and comfortable, while using a tiny fraction of the electricity of a typical on-grid home.

Conventional homes are seldom designed and built to this level of efficiency. Here's one way to look at the difference: A typical PV power system that can supply about three kilowatt-hours worth of electricity on a winter's day might cost $15,000 or more. With a small amount of backup generator power during cloudy periods, this is ample to meet the needs of a family. Supplied by the utility company, the bill would be less than ten dollars a month, plus base charge and taxes! Few utility customers have bills this small, because few have done the load shifting and high efficiency improvements necessary to live comfortably on the amount of electricity supplied by an independent PV power system.

DC to AC

There is another key difference between homes supplied with utility power and off-grid homes. Power from PVs and small wind and hydro installations is low voltage DC power, and is stored in batteries. Inverters convert the stored DC power to conventional 120 volt AC power.

Most small appliances, lights, tools, and other electrical devices operate at 120 volts AC. Larger appliances such as electric heat, water heaters, stoves, dryers, and many well pumps operate at 240 volts AC. Heating water and cooking can be done by propane or natural gas. But a backup power system must be oversized with a step-up voltage transformer or two inverters operating together to run many well pumps. This adds to the cost and complexity of the backup power system.

Short Days & Cloudy Weather

If this isn't enough, Y2K will occur when the nights are long and the days are short. A winter storm that brings a week of cloudy weather means that little solar electric power will be available to recharge the batteries.

People who live off-grid typically use a combination of wise use, battery storage, and a backup generator/charger to weather these seasonal periods. When the batteries are depleted and the system is without generator backup, the only option is to stop using electricity and wait until the PV array can catch up. This might take several days or weeks.

Expert Opinions

Coming up with a successful backup power system is not easy. There are many questions, and they are not always simple. Opinions within the industry vary. What's best for the customer? What's best for the industry?

What's best for the planet? We contacted several experienced dealers and distributors, and asked them to share the practical advice they give to their customers and dealers with Y2K concerns.

These five renewable energy (RE) consultants from across the USA have years and years of experience dealing with system design and installation. Take a look at their opinions and approaches and formulate your own viewpoint and plan. Look to your local dealer or favorite national RE company for advice and support as well. Whether the "Y2K problem" turns out to be real or hype, we can use it to improve our situations. We can become more self-reliant, less vulnerable to all types of power outages, and also lighten our load on the planet.

Bob Maynard, Energy Outfitters

Energy Outfitters is a full line RE distributor and dealer with a storefront in Cave Junction, Oregon.

I ask my potential Y2K customers what electrical loads they see as essential. The most common concerns are water pumping, refrigeration, heating, and lights.

Most often it's too expensive to build a solar system to run the existing 220 VAC well pump. Some choose to install a separate DC pumping system, and others use a generator and storage tank. Many clients have RVs with a generator large enough to run the existing well pump, although a step-up transformer may be required. An existing RV can also become a backup system for other needs, with its propane appliances and 12 volt system in place.

I shoot down refrigeration concerns right off the bat, unless required for medicine storage. It's just not cost effective to build a PV system to run a typical inefficient refrigerator. If Y2K hits hard, what fresh foods will be available that require refrigeration? Why not just keep perishables on the back porch during the winter? If some form of refrigeration is essential, a propane fridge is a viable option.

For heating, I recommend a woodstove or an efficient direct vent propane heater that requires no electricity. Being able to close off unnecessary rooms will reduce fuel consumption. This investment will have continued use and benefit in the future.

Lighting is often less of a concern, but during the short winter days, good lighting is necessary for practical reasons and for keeping up our spirits. This is where a small stand-alone PV/battery system can help out, powering a few DC compact fluorescent lights and maybe a radio.

Many on-grid people who have been dreaming about an RE system are now coming to us, nudged by Y2K. If they are serious and committed to the technology, we do a full load profile and design a system capable of interacting with the grid. We specify the most efficient appliances, so their investment will become a rewarding success.

Probably my best advice to people looking for an RE system for backup is to know who you are talking to. It's sad for me to see the quick buck artists jumping into this industry with little or no knowledge of RE. Check your potential dealer's references and find out how long he or she has been doing business. And if you're an off-gridder dreaming of a new backup generator, you may want to wait until next year. I suspect the market may be flooded with barely used generators!

Steve Willey, Backwoods Solar Electric Systems

Backwoods Solar is a full service renewable energy catalog sales company based in Sandpoint, Idaho.

I suggest a three step approach to backup power that is less costly, and may have practical applications for the rest of your life, with or without the Y2K crisis.

1. An industrial quality backup generator is useful for "normal" power outages as well as Y2K projections, as long as you have fuel for it. If properly sized, it can take over most or all the electrical needs of your home for a lengthy period determined by your fuel storage. An adequately sized generator gives full house power for those hours of the day that you choose to run it. No changes within the house are

required other than having a licensed electrician install a transfer switch between the utility and your generator.

2. If you wish to enhance the convenience of your emergency electric power, consider adding batteries and an AC inverter/charger. The batteries are charged originally from the utility, and from the generator when it is running. Then the inverter uses that battery power to supply a limited amount of 120 volt AC household power 24 hours a day, even when the generator is not running. It can't power your whole house, but you can run a cord to a few energy saving lights, power tools, vacuum cleaner, computer, TV, juicer or food blender, and more.

3. Solar electric modules are not usually recommended for utility connected homes, but might be considered for long term Y2K concerns. They can be added to the battery and inverter system, described above, to charge the batteries entirely independent of utility or generator power.

One or two KWH per day obtained by solar electric charging will not operate most houses designed for utility power. Yet the addition of solar modules will allow operation of the limited battery backup system described above, except in extended cloud cover or snowfall when some charging by the generator may be needed.

PV is the last step suggested because it is the most costly part, and the least likely to ever be needed in a utility backup situation. To make a solar charged "Y2K backup" power system most practical, install it on an RV or at least design it for later use on a summer cabin or boat. Then it will be a sound investment for the rest of your life if Y2K does not disrupt your utility power.

Windy Dankoff, Dankoff Solar Products, Inc.

Dankoff Solar is a national distributor of PV and wind-electric components and a manufacturer of solar water pumps based in Santa Fe, New Mexico.

My comments will be addressed to dealers and contractors, since we are a wholesale distributor. First of all, understand that you may be dealing with people who don't know the first thing about electricity, and don't want to learn. You cannot expect to do a complete load analysis. You have to take a simplified approach. Ask them to specify what appliances have priority, how many light bulbs, etc., and make your best estimate of KWH/day.

You may want to write a contract that specifies the KW of generating potential and the KWH of system yield that you are providing. These jobs can get complex. Align yourself with a distributor who provides the technical support and service that you'll need. That's more important than rock bottom pricing.

Plan to be in this for the long haul. Y2K may look like a short-term boom, but I don't see it that way. Recent history may offer a precedent. In the early '80s, our business boomed because New Mexico residents received a 40 percent federal tax credit plus a 25 percent state rebate for renewable energy purchases. Both programs expired on December 31, 1985. I expected 1986 to be slow, but it wasn't. By August, our 1986 sales exceeded those of '85, and we kept on growing. I expect a similar momentum to occur after the end of this year. So, do your jobs right and we will all benefit in the long run.

Tom Bishop, Sunelco, The Sun Electric Company

Sunelco is a retail and catalog division of Golden Genesis, based in Hamilton, Montana.

When Y2K inquiries started trickling in early last summer, we were pretty confused about what to supply our customers for a backup system. In a total sustained power outage, the basics of life must be met—water, heat, shelter, food, and light.

To attempt to supply them all with a renewable energy system just didn't seem cost effective or realistic, so we focused on the parts we could accommodate—mainly water, light, and refrigeration. Whenever possible we try to supply an alternative source to provide these necessities. On the other hand, it isn't practical to rip out your existing AC pump and put in a hand pump on the chance that Y2K might disrupt the grid.

So our systems became more of an "increase the efficiency of the typical home" approach. If you can possibly substitute a smaller or more efficient load for a larger one, do it. This means converting to compact fluorescent light bulbs, an energy efficient refrigerator, and a lower volume, smaller horsepower well pump. Now we've got something we can actually design around that we hope will be of use to our customers (and the planet) after the Y2K bug has been squashed.

The next concept is to limit operation times of even our most efficient appliances to keep system costs down. It is also important to keep the system as simple as possible so that the homeowner can install and maintain it.

Don't put all your eggs in one basket. In other words, have more than just one way to charge your battery bank. Even a stinky little gasoline generator and an automotive battery charger can be a lifesaver when the sun won't shine, the wind won't blow, and the diesel fuel is all gelled up. The biggest and best inverter is useless if the batteries are dead and you have no way to charge them.

Phil Undercuffler & Allan Sindelar, Positive Energy

Positive Energy is a full service PV dealer in Santa Fe, New Mexico.

Early on, we ask what type and duration of disruption the client wants to prepare for. Intermittent utility outages suggest a very different approach than a month's blackout. We also ask what the essential power requirements will be. After all, for most clients these are emergency systems.

As a rule, we don't do standard packages. Every PV power system is custom-tailored to the unique loads, lifestyle, and budget of the end user. Y2K backup systems, however, are an exception. We have designed five backup power packages with a wide range of capability and cost, each defined by what problem it can solve.

Our most basic packages are PV and battery systems designed to run efficient lights and small 12 V appliances such as a radio, CD player, or cellular phone. Each includes lights, a NiCd charger, and a voltage converter that will power almost any small battery device. The larger package adds a small inverter/charger and doubles the PV array.

Water pumping is considered a critical need by many here in the arid Southwest. Starting an AC well pump can be the most demanding task a power system will face. But we don't suggest that people replace their entire water system with an efficient RE system just for Y2K. Our two largest packages are designed with adequate inverter surge capacity to run an existing 220 VAC well pump, as well as other household appliances, at any time of night or day. A Kohler propane generator, sized to make maximum use of the inverter's charging ability, is included in each of these systems. Both of these systems are preassembled but require interconnection with the home's AC service panel by a licensed electrician.

Our middle solution is a portable battery/inverter system with no charging source included. It works with a client's existing contractor-grade generator to run a refrigerator, freezer, or furnace fan, with no intertie to the house wiring.

We harbor some strong reluctance to even offer the larger generator-based systems. Are we merely feeding the illusion that we can spend our way to security? Our blind reliance on technology has caused the Y2K problem; to expect more technology to solve it is folly. If our collective focus remains on autonomy and independence, we've missed a great opportunity. Our best clients have shown us that Y2K is a wake-up call to reduce our needs, build community, and live more simply.

Access

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N
W
E
S

TEOTWAWKI

…Not!

Nikolai Alexanderovich Zarick

"The end of the world as we know it (TEOTWAWKI)"…"These are the end times"…"Life will cease at the stroke of midnight on January 1, 2000 AD." Yada, yada, yada, will somebody give me a break already!

It all sounds so dark and gloomy—perfect fodder for movie scripts. But I happen to have faith in the god force, humankind, the Gaia hypotheses, and common sense. We have enough crucial issues to handle without manufacturing any more, and that is especially true for panic caused by a calendar change.

History Repeats Itself

The beginning of a new millennium has always fueled doomsday hype. 1000 AD was a prime example. Hundreds of sects and groups were caught with egg on their faces when the millennium change came and went without so much as a whimper. History seems to be repeating itself all over again, as it always does.

We don't know the exact birth date of Jesus Christ, which was the benchmark for the start of the Roman calendar. So the millennium's beginning could have already passed, or it could be several years from now. And many people think it begins on January 1, 2001, not 2000. Whenever it is, it's an artificial date, which serves the mass media and advertising agencies.

The universe is not going to collapse, it's expanding, so pay your bills and don't let your magazine subscriptions run out. You're not getting off the hook that easy.

This is definitely the time for a Brobdingnagian "new think," and we must start scheduling personal time to actively correct the woes of our global society. But the only thing most Americans will be worrying about on New Year's Eve, 1999 is where they will let their hair down and go wild. And oh yeah, there is that little Y2K thing.

Two Digits

Just in case you have been meditating on some mountaintop for the last year or so, the Y2K (year 2000) bug fundamentally comes down to two little digits. In an effort to save computer chip memory space, programmers decided to use the last two digits of a year's date, instead of all four. So when 1999 (which is read as 99) rolls over to 2000, it will be read as 00. The popular belief is that millions upon millions of the older computer chips will interpret 00 as 1900. This little boo-boo will cost the world 1.6 trillion U.S. dollars.

Many of the computer chips act as timed switches and will either lock in the open or closed position. So your automatic coffee maker may shut down, or it may stay on, potentially creating a fire hazard. You can basically apply this concept to everything that has a computer chip. Just try to find anything electronic that does *not* have a computer chip these days….

The Y2K problem is the ultimate oopsy. It's a huge wake up call, telling us that we are much too dependent on "the machine." I love the digital age as much as I loved the days when Lao-tse rode his ox. I like most of the newest gadgets as long as they are environmentally friendly, and I would not want to do without most of the labor saving devices and toys of our time. Yet this Y2K thing is teaching us that we must step back and re-examine how much control we really want to surrender to ones and zeros.

Bad Chips or Panic?

I predict that most of the predominant computer controlled systems in the western hemisphere will function as required. I do have some serious doubts about the readiness of the techno-dependent systems in many of the developing countries.

I think the *real* problems (as opposed to the onslaught of imaginary Y2K problems) will be caused by *panic.* I'd liken it to panic before a big storm, which causes consumer goods shortages, highway blockages, and bad hair days. There might be a ludicrous run on the banking systems; many of Wall Street's finest will dump their stocks off the market. People will stockpile what they think they will need for TEOTWAWKI, and all of this will give the survivalists the excuse to start eating their yummy freeze-dried ice cream as they flee the urban sprawl.

It won't be the military weaponries or the air traffic control systems that will have troubles, it will be things like the coffee maker I spoke of. The life support systems in hospitals and home care, irrigation systems, public water and sanitation networks, along with a whole myriad of the seemingly minor systems, will cause a ripple effect like the flutter of the butterfly's wing in the chaos theory.

Y2K is a Luddite reverie. All of this jabber in the mass media of the breakdown of "the machine" makes me

want to flip through the pages of *Lehman's Supply* catalog, and read the *Foxfire* book series and *Walden* again. But I am not a subscriber to "the end of the world as we know it" mentality, though I do love that song by *They Might Be Giants.*

Don't Worry!

So! What do we have to do to save ourselves from the computer chip hydra lurking in the shadows? *Relax!* That is the key word for the whole Y2K problem. Nut trees will keep growing and will provide sustenance. The flowers will bloom in the spring of 2000, giving the killer bees lunch before they eat you for dinner. And the crickets will sing as they bring our homes good luck on summer nights. *It's all going to be OK!*

If you're still pulling your hair out over this Y2K thing, you probably have way too much time on your hands. Go out and split some wood, plant a forest, fill your bird feeders, cook for your lover, something…. Just "chill out."

I suggest that shortly before December 31, 1999, those of you adrift in cyberspace should back up all your files onto disks and make hard copies of all your fave stuff. And pull your acoustic instruments out of your attic, because you may be in store for at least a brief period of some serious retro-modus vivendi.

Yawning Off-gridders

For you "back to the earth" folks, stop yawning—for you it will be just another day. If you are off the power grid, it doesn't really matter. I am reminded of an Amazon native who was asked, "Did you hear the news? Venezuela has given you independence." He replied, "What's Venezuela?"

And there it is, if you're not techno-dependent, you'll say "what Y2K?" Millions of the earth's inhabitants on New Year's Day 2000 will be communing with their porcelain deity, waiting for their champagne headache to dissipate, and will be picking confetti out of places they didn't know they had.

The Y2K trip will most likely be over in a couple of days, or at most a week, and "Hal" will open the pod bay doors again.

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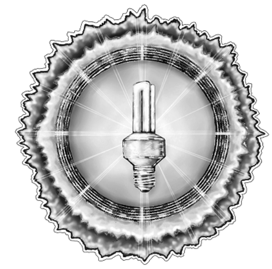

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From "Fall Mountain," watercolor by Benjamin Stein.

It's Easy to Cut Your Utility Bills, Save Energy, and Help the Environment!

Eric Eggleston

We all know an unattractive way to save energy: sit at home, freezing in the dark. Luckily, there are some easy steps we can take, without ruining our comfort. Using what I learned about energy, I cut my bills almost in half!

I insulated my attic ($200), installed some compact fluorescent light bulbs ($75), replaced an electric stove with a gas model donated by a friend (free), and replaced my fridge with a more miserly manual defrost model ($30). Though my home is small, these changes paid for themselves in about a year. All you need is a little investment, elbow grease, and knowledge. Stop fuming at monthly bills and do something about them!

Apples vs Apples

One of the first things to do is choose the best energy source for each task. You'll need to decide what "best" means for you. It could mean least cost, lowest pollution, safest to use, or most easily available in your area. If lower energy *costs* are your main objective, comparing fuels according to energy content is important.

Fuel Costs (equipment costs not included)

Fuel (Unit)	*Unit Cost (Dollars)*	*Million BTU per Unit*	*Dollars per Million BTU*	*Cents per KWH*
Electricity (KWH)	$0.08	0.003	$24.69	8.42¢
Natural gas (KCF)	$9.10	1.499	$6.07	2.07¢
Fuel oil (gal)	$0.90	0.139	$6.46	2.20¢
Kerosene (gal)	$1.09	0.135	$8.08	2.76¢
LP gas (gal)	$0.92	0.092	$10.04	3.43¢
Wood (cord)	$125.00	20.000	$6.25	2.13¢
Wind (n/a)	Free	n/a	$0.00	0.00¢
Sun (m^3)	Free	3412.000	$0.00	0.00¢

Wood costs calculated with 20 million BTU / cord at $125 / cord.

Two commonly used energy units are the kilowatt-hour (KWH) and the British thermal unit (BTU). Your electric bill is measured in KWH. A 100 watt light bulb lit for 10 hours uses 1 KWH. A BTU, often used for home heating calculations, is the amount of energy required to raise the temperature of one pound of water by one degree Fahrenheit (3,412 BTU = 1 KWH).

The table shows the average U.S. energy costs for various fuels. This information is from the Department of Energy's book *Household Energy Consumption and Expenditures 1993*. Look at the average prices in the table. If you currently heat your house with electricity, you could switch to natural gas, fuel oil, or wood, and cut your heating bill by 75 percent! This also applies to electric water heaters, electric stoves and ranges, electric clothes dryers, baseboard heaters, electric bathroom heaters, and portable electric heaters—the list is long.

Efficiency and Pollution

"But wait," you say, "electricity doesn't pollute." Well, that's not exactly true. Utility electric power plants burn a fuel to run a turbine, turn an electric generator, form magnetic fields, and cause electricity to flow in wires. Since converting energy from one form to another is absolutely always an energy losing proposition, electric power plant efficiency is less than 100 percent—actually much less—despite great efforts to improve it.

Our modern power plants are usually able to convert only 40 percent of the fossil fuel energy to electricity! A generating plant using the latest combined cycle technology might, perhaps, convert 60 percent of the energy into electricity. About half of the energy in the fossil fuel a utility plant burns is lost up the stack and into the atmosphere—only to come back as pollution, climate change, and greenhouse gasses.

For example, if you cook on an electric stove, the utility power plant burns fuel to make heat. The heat runs a turbine generator, which produces electricity. The electricity runs through miles of wire to your house and

gets turned back into heat to cook your food. Meanwhile, an equivalent amount of energy is permanently lost. Needless to say, you have to pay for all the fuel burned on your behalf, capital investments in power plants and electric transmission lines, employee salaries and health insurance, and utility profit. As a bonus, you get to breathe the resulting polluted air.

Now, if you burned a fuel at home to cook your food, perhaps 90 percent of the energy would actually get used to heat your food, with the remainder heating the kitchen. You would accomplish the same cooking objective, while burning much less fuel and producing far less pollution and heat to be dumped into the atmosphere.

Investing in Efficiency
Using any fuel requires that you buy appliances and equipment that run on that fuel. Usually, the more you invest up front on efficient appliances, the less you will spend down the road on energy and operation. If you're willing to spend quite a bit up front for passive solar home design, wind turbines, solar thermal, or photovoltaic panels, operating fuel costs can be removed completely. These renewable energy options may also be attractive because they don't contribute to pollution.

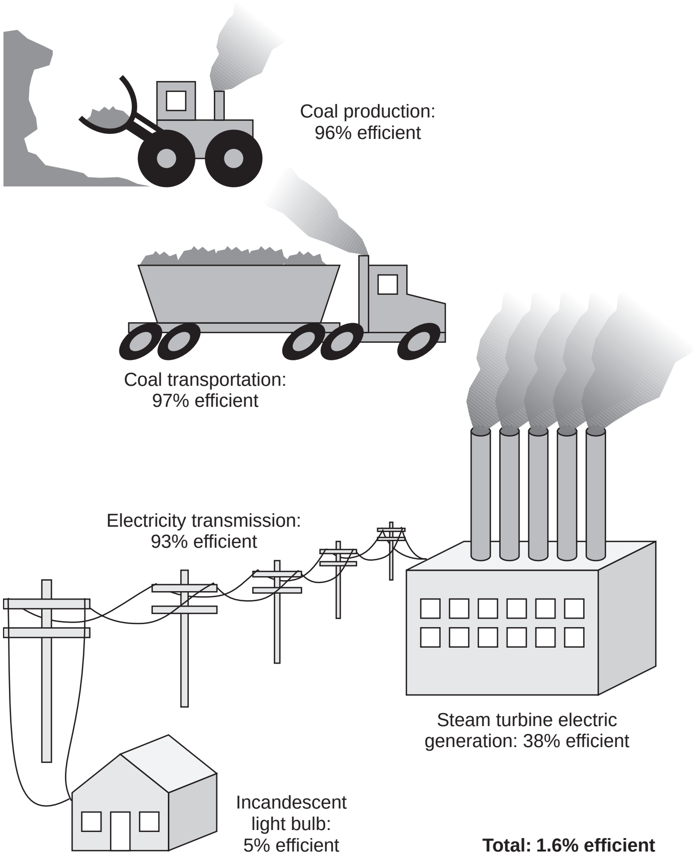
What to Do
By using the information above and following these recommendations, you can probably cut your energy bills in half:

1. Get in the habit of turning off lights, closing doors, doing full loads of laundry, and hanging out clothes to dry (if possible). Wash full loads of dishes, and minimize the number of times you open the fridge or drive to the store. Changing habits may be difficult, but it's free. Waste not, want not.

2. Change to compact fluorescent (CF) light bulbs in the fixtures you use most. This may be one of the easiest ways to cut energy costs and help the environment. Most people are familiar with incandescent light bulbs. Take a look at the packaging—these usually last between 750 and 1,000 hours before they burn out. CFs last about 10,000 hours.

Compact fluorescents provide the same light intensity, but use a scant 25 to 35 percent of the energy of incandescents. Newer models are color balanced and don't flicker, making them much easier to live with. One CF bulb lasts 10 to 13 times longer than a standard incandescent bulb and uses up to 75 percent less energy. The high initial cost of CF bulbs, $15 to $20 each, must be compared to the cost of ten incandescent bulbs and the increased cost of running them.

Compounding Efficiency of Coal to Light



Numbers from *Wind Energy and Wind Turbines* by Dr. Vaughn Nelson

If you live in a climate that requires air conditioning, there's a hidden secondary savings too. Switching to compact fluorescent bulbs means that your lights will dump much less heat into your home that your air conditioner must then remove. CF bulbs usually take a fraction of a second to light, which isn't bothersome once you're used to it. In the end, they are a much better economic investment and environmental deal.

3. If you heat anything with electricity, take the next opportunity to change to a cheaper, more efficient fuel. Electric central heaters, stoves, water heaters, clothes dryers, baseboard heaters, electric bathroom heaters, and portable electric heaters should all be on your "hit list." Eliminate them, repower them with an efficient fuel, or use an alternate method.

Natural gas and fuel oil are economical heating choices, if available. Wood has long been used to heat homes, and newer wood stoves are much cleaner and more efficient than in the past. They require much less wood and therefore less work cutting, splitting, lugging, and stoking. Since wood is part of the natural carbon cycle, burning it shouldn't really count as greenhouse gas emissions. Solar home and water heating is a great

way to help the environment too, if you can afford the initial investment required and have an adequate solar resource.

4. Insulate and caulk your home to retain as much of your costly warmth (or air conditioning) as possible. Since normal glass windows have very low insulation values, you might consider double glazed energy efficient windows, or sealed storm windows.

Air conditioning is a huge user of electricity in the warmer parts of the U.S. The amount of energy required to keep your home's interior comfortable depends on the insulation and the temperature outside. Improving the insulation and lowering the temperature difference will reduce energy requirements. Since the underground temperature is steady and is not far from what you'd like in your house, a geothermal heat pump may do the job, using much less energy. It might cost more to install, but can be cost effective and environmentally friendly as well.

In a solar heated home, the panels can perform double duty. You can allow circulation through the panels at night, thus collecting the cool of the night to be used during the next afternoon.

In the Southwestern U.S., where the air is dry, evaporative cooling is a good way to keep comfortable at low cost. A big fan draws air through wet jute mats, causing some of the water to evaporate. As the water evaporates, it cools the air, which is then blown into the house. This takes much less energy than central air conditioning, which is actually the same type of system your refrigerator uses, only bigger.

5. Get the best, most efficient appliances you can, whenever you have the opportunity. Refrigeration is a significant part of domestic energy consumption, so you might consider getting the smallest, least gluttonous refrigerator that will meet your needs. Nearly 33 percent of the energy in modern refrigerators goes to little heaters used for automatic defrosting, so you might consider a model without this feature. Also, over the life of an electric motor, the cost of electricity is typically many times the cost of the motor itself. It makes sense to get a more efficient model.

Utility bills must be paid, but information is free. Armed with what you have read, I'm sure you can find other ways to reduce your energy consumption and bills. It isn't as hard as you might think!

Going Further

Find Benjamin Root's article *Doing a Load Analysis, HP58,* page 38 (also available on the *HP* Web site), and Michael Lamb's article *Phantom Loads, HP55,* page 36. Perform a load analysis for your home as described. Measure the energy consumption of each of your appliances. You can use a multimeter to measure their volts and amps, and multiply them together to get watts going to each appliance.

Or, if you prefer, you might purchase a power meter. Check with renewable energy vendors to see what is available and get some solid figures on the energy use of your appliances. List all your appliances from highest to lowest annual energy usage. Start at the top of the list—eliminating, changing, controlling, and conserving.

If your house is initially rather gluttonous and you are willing to be fairly ruthless about decreasing overconsumption, by the time you reach the bottom of the list, you will have probably cut your consumption more than 50 percent. By applying the same load analysis technique to your heating, cooling, and other bills, you may cut them drastically, too.

Access

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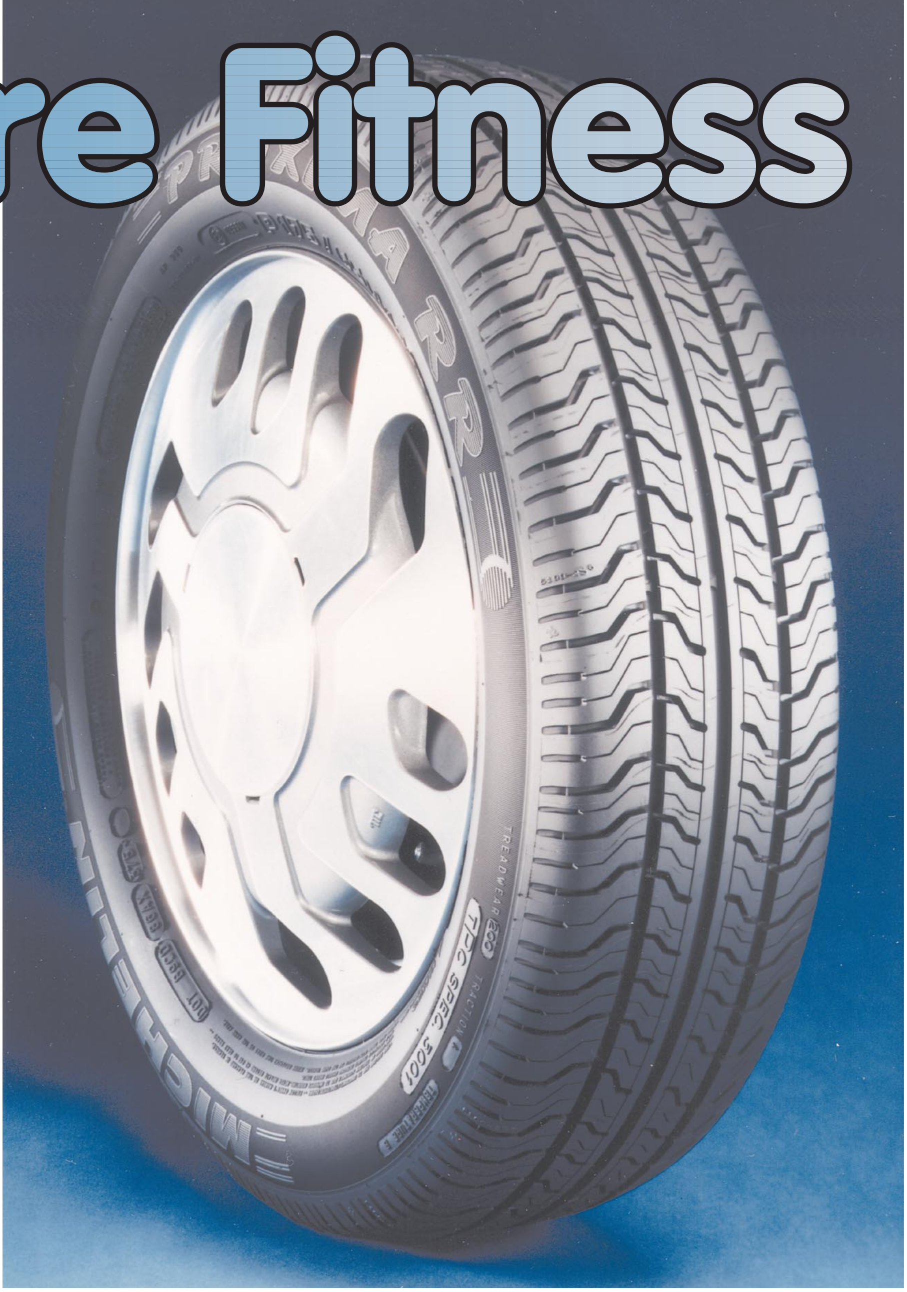
EV Tire Fitness

Shari Prange



When people talk about electric cars, they most often talk about endurance. How long will it run before I have to recharge? It's easy to fixate on the batteries as the most obvious factor in range. However, there are a lot of other, smaller factors that can make a difference. One of them is tires.

Feeling Sluggish?

Tires are the interface between the vehicle and the road. This interface is critical for acceleration, traction, handling, ride smoothness, and rolling resistance. That final item is the one you want to minimize to achieve the best possible range.

Electrical energy from the batteries becomes mechanical energy in the motor, then passes through the transmission and out to the wheels. Rolling resistance refers to anything that sucks away some of that energy from the wheels and diverts it from its useful function in moving the car. Usually, this means energy that is simply wasted as heat. If this waste can be reduced, then more energy is available to turn the wheels and move the car.

Lose Weight & Gain Energy

One way to improve rolling resistance is to decrease the weight load on the tire. This means making the vehicle as light as possible, but it also means making the tires as light as possible.

The weight of the tires may seem trivial in comparison with the rest of the car, especially the battery pack. However, tire weight is rotational weight—it spins. It takes more energy to spin this weight than it would to simply move it in a straight line. Saving ten pounds (4.5 kg) off each tire will have more effect on rolling resistance than saving the same forty pounds (18 kg) in battery weight.

Staying In Shape

Another way to improve rolling resistance is to decrease deflection of the tire. Tires are round, but as they bear down on the pavement, they flatten and the sidewalls bulge. As that portion of the tire rolls up off the pavement, it becomes round again. The tire also deflects even more if it rolls over bumps or potholes. This constant flexing and unflexing causes energy to be wasted as heat. This is the largest factor in rolling resistance in a tire.

As the tire rolls down the road, it deflects in both the tread and the sidewall. The deflection of the tread is the most critical to rolling resistance. If the tire can be redesigned so that a greater proportion of the deflection occurs in the sidewall and a lesser proportion in the tread, rolling resistance will be reduced.

Substitute Ingredients

Some of the same engineering techniques can be used

to reduce both weight and deflection. For example, different materials and construction techniques can make a tire that is both lighter in weight and more rigid.

A tire is not just a big rubber doughnut. There may be as many as a dozen different compounds used in different parts of a tire. The tread is made from a different compound than the sidewall, for example. Tires also have multiple materials used in the belts and various reinforcing layers.

In the past, our tires have been steel-belted radials. But in the future, they'll be textile-belted. No, I don't mean hemp cloth. In this use, "textile" refers to well known materials such as polyester and nylon, and less familiar materials that are strong but lightweight, such as Kevlar Aramid fibers. These materials make the tire both lighter and more rigid.

The rubber is changing, too. Rolling resistance and traction used to be on opposite sides of a scale—if you improved one, you sacrificed the other. Then tire makers discovered that they could substitute silica for some of the carbon black in the rubber compound. This breaks the stalemate. Now you have a compound with low rolling resistance and good traction at the same time.

Building Up

The materials are important, but the way they are put together is just as critical. Some low rolling resistance tires have less tread depth than normal. This might also mean a shorter lifespan for the tire, but it might not, if the tread compound is also adjusted. Other low rolling resistance tires, such as Bridgestone or Firestone, will have the same tread depth as normal tires.

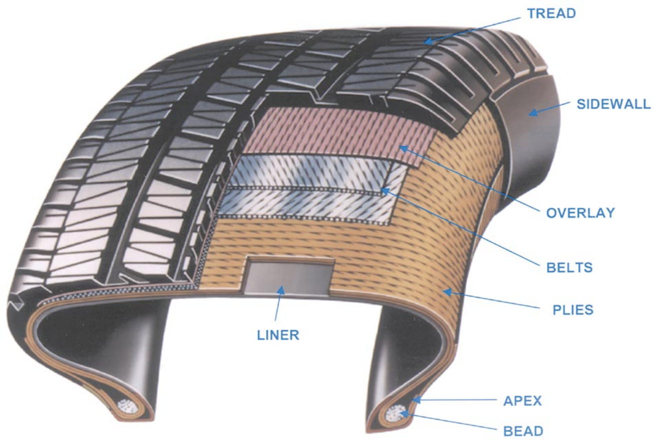
Different manufacturers may focus on different methods to reach the same end. Bart Thompson, tire engineer for Michelin, emphasizes a flatter crown, which is the shape of the top of the tire when seen head-on. Mike Weber, Goodyear tire engineer, stresses a taller sidewall and narrower relative tread.

In addition to all of the factors we've already talked about, manufacturers have one more structural issue. They have to design their tread patterns to try to minimize road noise. Electric cars are quiet, so tire noise is more apparent.

The challenge that manufacturers face is to balance all these factors, producing the best total tire package. For example, traction and handling cannot be allowed to fall below acceptable levels in order to achieve low rolling resistance. A tire that deflects less will also give a stiffer ride, so driver comfort becomes an issue.

Lighter materials and thinner sidewalls may mean more susceptibility to sidewall damage. This is less of an issue on a car like the Honda EV Plus, where the tires are fully warrantied against road hazards as part of the overall car package. It might be more important on a conversion car without Honda's warranty.

Tire Construction Cutaway



Courtesy of Goodyear

Know Your Limits

Materials and construction are in the hands of the tire manufacturers, but there are things the car owner can control to reduce rolling resistance too.

The tire should be properly matched to the vehicle. It's very important to stay within a tire's rated specs—it was designed for these specific conditions. Using it outside of these ranges will not yield the best performance, and may actually be unsafe.

Most conversions add several hundred pounds of weight to a car. For this reason, the tires originally specified for that model may no longer be the best choice. You should choose a tire in the correct size that is rated for the car's converted weight.

Ordinary "Standard Load P-metric" tires are rated for maximum load capacity per tire at a standardized 35 psi inflation. Additionally, there are Extra Load P-metric tires, primarily available in sizes for light trucks. These tires can carry more weight because they are rated for maximum load capacity at a standardized 41 psi inflation. If your vehicle requires more load capacity than standard load tires can provide, you should investigate the availability of extra load tires.

A tire with more air volume is capable of carrying more weight. Within the limits of the space available in your wheel well, a larger tire could help carry the extra weight and improve your range. If you are running a tire at its maximum load capacity, the rolling resistance will be worse than a tire run at a fraction of its load capacity. This is because the tire at its load limit will have more deflection. In other words, tires that are rated higher

than necessary for your vehicle's weight will give better range performance, all else being equal.

Breathe Deep & Stand Straight
Inflation is very important. A soggy tire will waste a lot of energy. But just how much should you inflate it? Many tires designed for electric cars have been engineered to run at higher than normal inflations. This is part of stiffening the tire. Troy Cottles of Dunlop says the Dunlop DEV-01 issued on the Honda EV Plus is rated for 51 psi. Jorge Pena of Michelin says the Proxima RR is rated for 55 psi.

It is not a good idea, however, to simply take an ordinary tire and run it at a higher inflation pressure. All of a tire's handling characteristics and ability to withstand stress (like hitting potholes) have been engineered for its designated ratings. Once your conversion is completed, it's a good idea to immediately confirm how much weight your vehicle's tires are carrying. Then select a tire size designed to carry that weight, and only use inflation pressures within that tire's specifications.

Higher inflation improves range by reducing tire deflection. In the past few years, many tire manufacturers have begun increasing the maximum allowable inflation on their tires, in the expectation of future fuel crises. Most of these tires can be inflated as high as 44 psi. This number will be stamped on the sidewall. Running these tires will allow you to use a higher inflation and save energy.

Your inflation needs to be keyed to your car's weight distribution as well. If your car is slightly lighter in the front or rear, reduce the inflation at that end. But don't go below 90 percent of the inflation pressure being used on the heavier end of the vehicle. Also, be sure your car is properly aligned. Bad alignment will wear out your tires unevenly and prematurely, and it will cost you range while it does so.

Same Shoes the Pros Wear
So how do you find a specific tire for your car? For starters, don't even think about using old fashioned bias-ply tires on your electric car. They simply will not stand up to the weight, torque, and handling stresses involved.

There are currently only a couple models of tires specifically designed for electric cars, and they aren't available in all sizes. One is the Michelin Proxima RR, which is the tire for the GM EV-1. This is available by special order through Michelin dealers.

Bridgestone Ecopia tires are original equipment on the Honda EV Plus and the Toyota RAV-4 EV. Honda has also been working jointly with Dunlop on the DEV-01. This tire is only available in the 14 inch size of the EV Plus, and it can be ordered through Dunlop dealers. The stock number for ordering is 036141.

Beyond these, you need to look for tires developed for fuel economy on gas cars. Your best bet here is to look for tires that are issued as original equipment on new vehicles, particularly Japanese models. Auto manufacturers push for low rolling resistance tires to improve their Corporate Automotive Fuel Efficiency (CAFE) numbers. This number represents the combined fuel efficiency of their product line, and they are required to meet certain standards with it. The Japanese manufacturers have particularly strict standards for fuel efficiency.

Or Good Cross-Trainers
Conversely, there is very little interest in fuel economy from the public, so tires that are manufactured only for retail sale do not emphasize this feature. Goodyear went to some effort a few years ago to make and promote a low rolling resistance tire. While it was slightly more expensive than a standard tire, the fuel savings over the life of the tire paid for one tire out of four. The public, however, was uninterested.

There are still some low rolling resistance tires out there, though. Michelin's top seller in this category is the Energy MXV4. Other fuel efficient Michelin tires are distinguished by the "Green X" on the sidewall. In Dunlop tires, look for models with an "FE" (fuel efficient) or "RR" (rolling resistance) suffix on the model number.

While Goodyear is not promoting any specific models as fuel efficient, there are different models in various sizes that are suitable for electric cars, and have better than average rolling resistance. And Goodyear is offering personal consultation to help you choose your tires. Bill Egan has been a supporter of EVs for many years, and is generous in advising home converters. You can contact Bill for help. Tell him your car model, car weight, and weight distribution fore and aft, and he will give you the product code for the most appropriate tire as well as the optimum inflation pressure to run.

Listen To The Experts
Consumer Reports runs tire tests about once a year. Sometimes they test all-weather tires; other times it might be touring or performance tires. However, for any type of tire, they include a rolling resistance rating based on their own tests. This is another source of information for your buying decisions.

Another resource is John Rastetter, product information specialist for The Tire Rack, a nationwide business selling tires by mail order. John has many years of experience in the tire industry, and has a great deal of detailed technical information on a wide range of tires.

He contributed generously to this article on the subjects of load capacity, tire size, and inflation. You can contact John and he will help you determine the best tire and inflation for your electric vehicle.

Knowledge Is Power

Now that you have all this nifty tire information, how do you use it? First, you need to know what size tires fit on your vehicle, and how much the vehicle weighs. You can often find public scales at landfills, sand and gravel yards, and feed stores. While you're at it, get separate weights for each axle. Armed with this info, you can start tire shopping.

As a first choice, see if your vehicle matches the weight and tire size of any of the EVs from the major manufacturers: Honda EV Plus, GM EV1, Chevy S10, Ford Ranger, and Toyota RAV4-EV. If so, you should be able to find out the exact tire model, and maybe even the product order code, from an auto dealer who carries that model vehicle—that's your tire. Once you identify it, you can shop around for the best price. Just be sure that the salesperson is quoting you on that exact tire.

If you don't find a match, you need to dig further. Here's where Bill Egan and John Rastetter can be of help, or you can do research on your own. You know how much weight you need to support, and you would like the tire to be rated for even more weight if possible to improve your rolling resistance. Shop for tires that have the right size and weight ratings.

Next, search among these tire choices for any that indicate they were designed for fuel economy. This might show up as the "Green X" of Michelin, or the "FE" or "RR" suffixes of Dunlop. You can also check the *Consumer Reports* ratings, and you might find an excellent rating for a lesser known tire.

In the end, you might bring it down to a short list of possibilities. Find a knowledgeable tire seller, explain your needs, and get the help you need to make the decision among the final candidates. Just don't be led astray at the last minute by a sales pitch for some other tire unless the salesman can back it up with specifications.

The Holistic Approach

As you can see, there are a lot of factors involved in making a good electric vehicle tire, and these factors interact with each other in sometimes complex ways. What this means to you is that there is a lot more to buying tires than finding the best price, or even the best warranty. If you want to get the best performance from your electric car, you should think of the tires as an integral and important part of the overall system. In the long run, the best match of tires to vehicle will be the best bargain.

Access

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LEAR FINANCIAL

full page B&W on negative

this is page 96

4000 Watt Standby Power System
Photovoltaic Modules
TRACE Sine Wave 4000 Watt Inverter Charger. 10,000 Watt Surge Power with 2800 Watt Charger. Fully programmable, including control of generator and relay closures. Stackable for double the power.
Dealers and installers needed immediately for Y2K market. We've got the customers if you've got the talent.
THE POWER COMPANY
Trace
ENGINEERING
2500 Watt Standby Power System
TRACE 2400 Watt Inverter / Charger
1500 Watt Solar System
TRACE 2500 Watt Inverter/ Charger
Wind Generator 600 to 3,000 Watts
13 KW Inverter Generator System
Dynasty Gell Cell, 12V, 90 AH
Trojan 12V @ 117 AH
Trojan T-105, 6V @ 220 AH
Surrete 6V Battery, 820 AH
SUN ELECTRONICS
INTERNATIONAL, INC
Tel: (305) 536-9917 / Fax: (305) 371-2353
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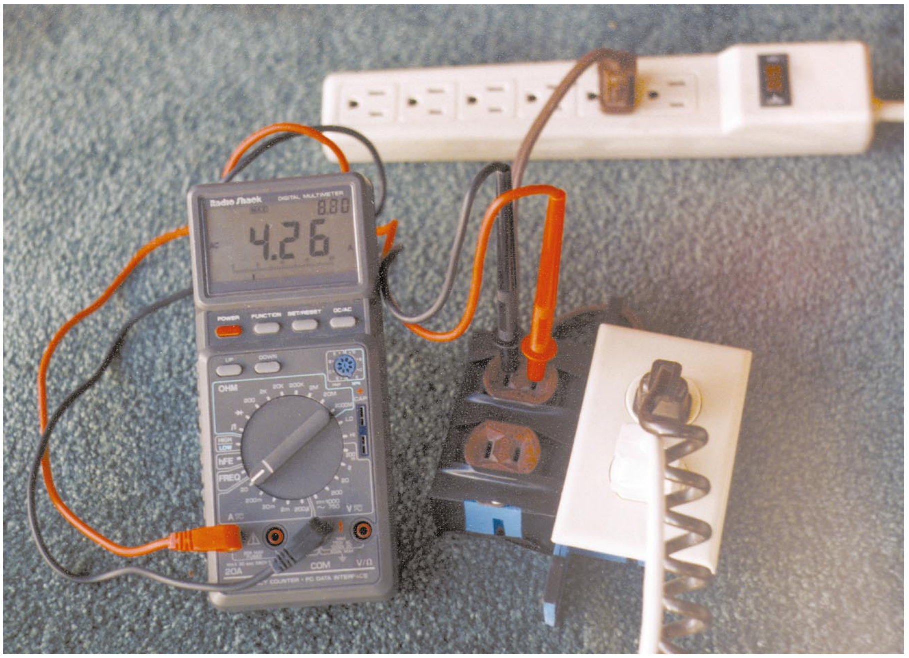
Power Consumption Monitor

Michal Vojtisek-Lom

I live with four other environmentally conscious friends in an old house in Pittsburgh, Pennsylvania. We try to reduce our electricity use, both to save on our nine cents per KWH utility bill and to prevent overloading our ancient house wiring.

We often get into debates about how much power our various appliances really consume. So to get solid answers, I came up with a simple device to use with my digital multimeter. Now I can easily measure regular and peak current, power consumption, and power factor.

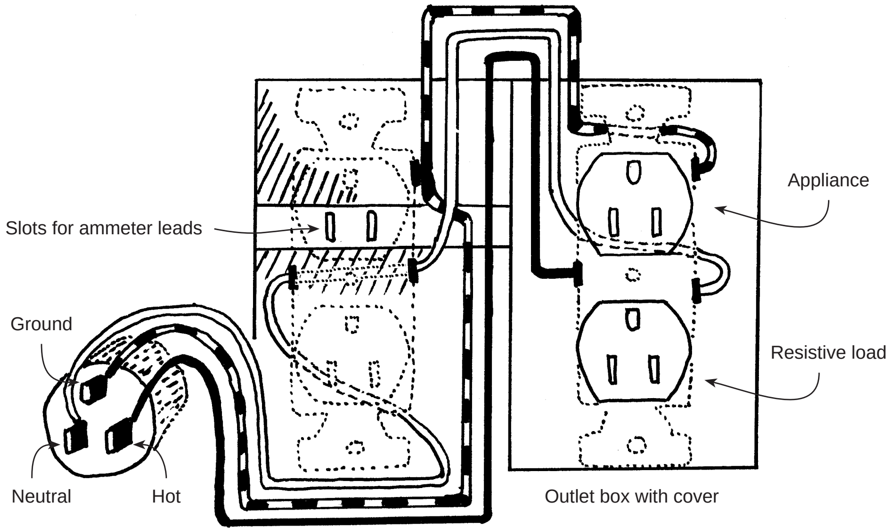


Current supplying the appliance and resistive load flows through the multimeter via the series-wired outlets.

A Simple Metering Device

The device consists of two standard AC outlets: we plug refrigerators, compact fluorescent lights, etc., into the “appliance” outlet; and we plug the multimeter into the “meter” outlet, one lead in each slot.

Wiring the Series Break-in on the Neutral Wire



The device simply plugs into any wall outlet, although a ground fault interruption (GFI) outlet or power strip with a built-in 15 amp breaker adds extra protection. The hot wire from the source is wired straight to the hot wire on the appliance outlet, and the neutral wire is routed through the meter outlet so that all the current goes through the multimeter.

Operation

The operation is straightforward. We set the meter to the 20 amp range, stick the probes all the way into the meter outlet, plug in the appliances, plug the device in, turn on the appliances, and watch the display (in this order). I use a Radio Shack digital multimeter with min-max data hold and a PC data interface. The max data hold feature automatically stores the highest current measured, which is useful for determining peak loads. For example, our refrigerator uses 19 to 20 amps when the motor starts, and 3 to 4 amps from then on.

Measuring volt-amperes on the vacuum cleaner, using the clip-on incandescent light as the resistive component.

PC Interface

The PC interface logs the readings onto a computer once every second. This is useful for measuring average consumption of varying and intermittent loads, such as PCs and refrigerators. The meter's PC software plots the readings on a graph. You can download the data into a spreadsheet and calculate total energy used or average consumption over a day. You can also look up the highest reading and find out the peak load of any given AC appliance.

Measuring Power and Power Factor

Calculating the power consumption and power factor can be tricky. For this, I plug a purely resistive load (a 40 to 150 watt incandescent light bulb) into the second slot on the appliance outlet. I measure three currents: I_R when only the bulb is on, I_A when only the appliance is on, and I_T when both are on. If Re(I) and Im(I) are the real and imaginary power components of current I, two equations hold:

$$1.\ [\mathrm{Re}(I_A)]^2 + [\mathrm{Im}(I_A)]^2 = I_A^2$$

$$2.\ [\mathrm{Re}(I_A) + I_R]^2 + [\mathrm{Im}(I_A)]^2 = I_T^2$$

From here, the real power appliance current is

$$\mathrm{Re}(I_A) = \left|(I_T^2 - I_A^2 - I_R^2)\right| \div (2 \times I_R)$$

and the power factor (PF, also known as cos Φ) is

$$PF = \mathrm{Re}(I_A) \div I_A$$

Power consumption is then calculated by multiplying the line voltage (measured with the multimeter or "guesstimated") by the real power current.

I hope you will find this useful. The cost of making this device is about US$5, plus meter, which many enthusiasts already have anyway. Let the sun shine forever.

Access

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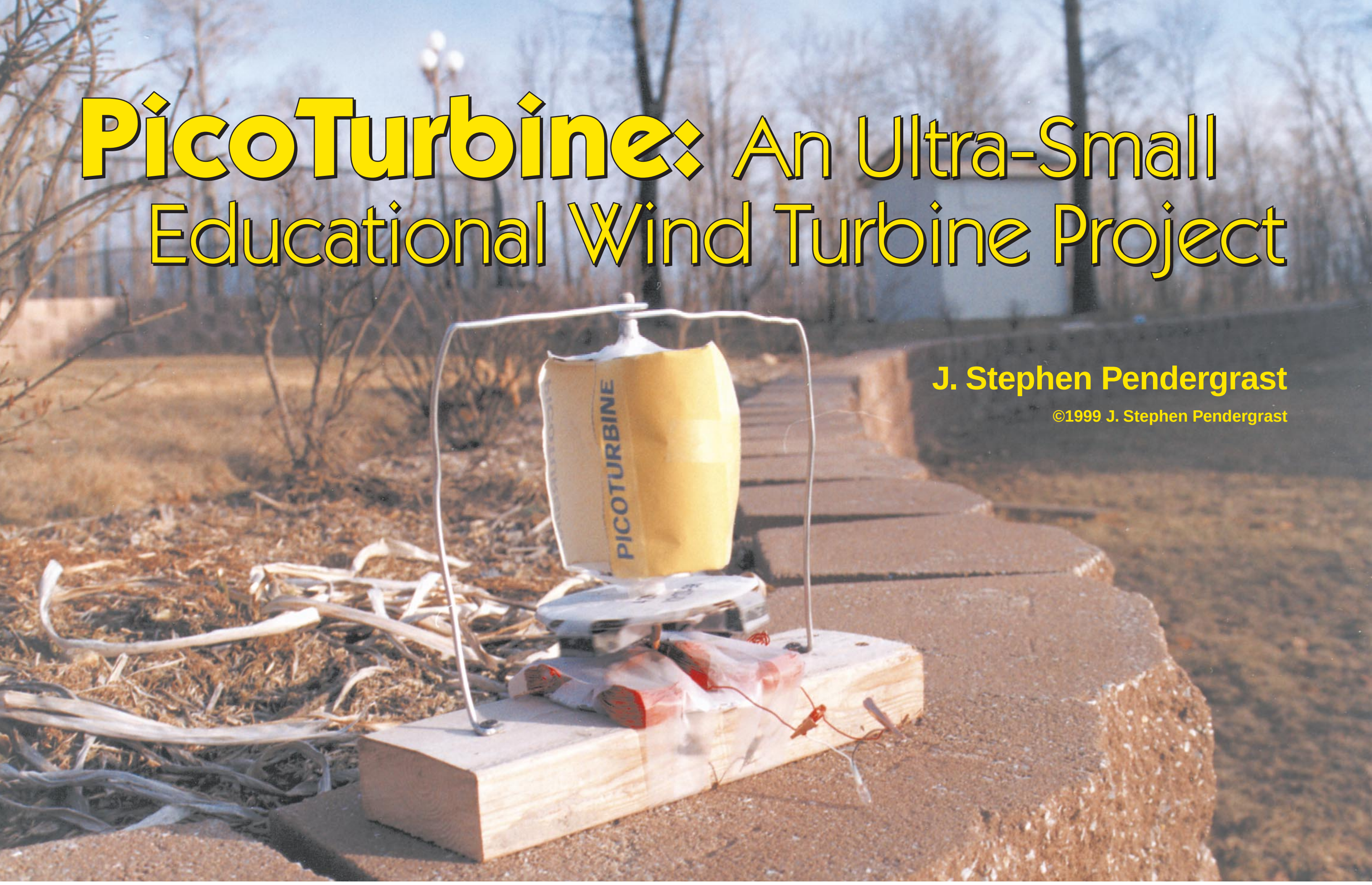
PicoTurbine: An Ultra-Small Educational Wind Turbine Project

J. Stephen Pendergrast



PicoTurbine can produce 1/3 watt—that's a lot of power when converted to education!

This article will show you how to build PicoTurbine—a fully functioning, electricity-producing scale model of a wind turbine. The entire project costs only a few dollars, and uses commonly available materials like magnets, cardboard, tape, wood screws, and a pencil.

PicoTurbine can be built in less than two hours. With some adult supervision, PicoTurbine can be assembled by children as young as ten years old, making it an excellent project for renewable energy education.

PicoTurbine stands less than 8 inches (20 cm) tall—but don't let its size fool you. This version of PicoTurbine produces about one-third of a watt of power from a direct-drive, single-phase, brushless, permanent magnet alternator. More advanced versions the same size can produce a full watt, but are more challenging to build.

The design is naturally self-limiting for overspeed protection. I've left mine out all night during a windstorm with 50 mile per hour (22 m/s) gusts that made my brick house shake. In the morning, I looked out my window—fully expecting to see it shredded—only to find PicoTurbine still spinning at top speed in the early morning gale!

Materials

You will need the following materials and tools to build PicoTurbine:

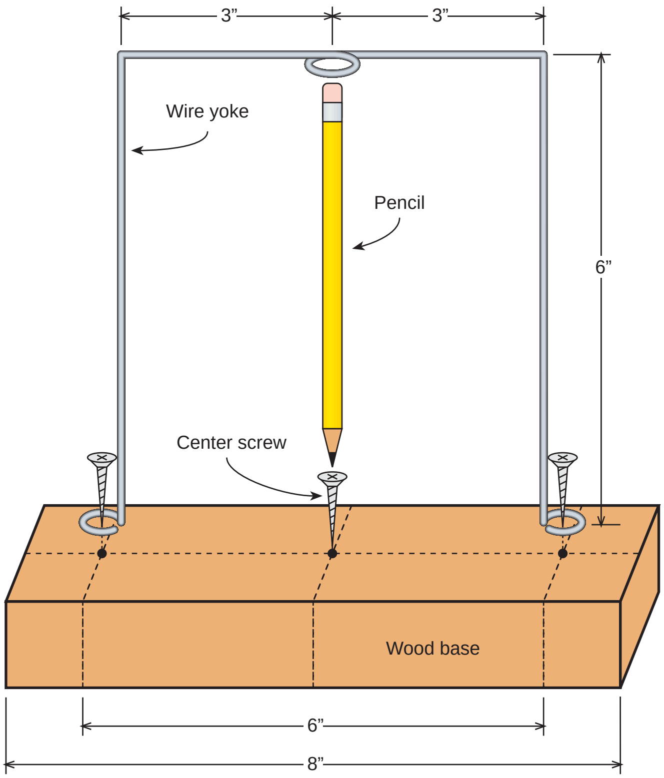
- A pencil.
- A piece of stiff wire about 2 feet (0.6 m) long. I use 10 gauge (5.2 mm^2) aluminum wire in this article, but a wire coat hanger will work if carefully straightened with pliers.
- An 8 inch (20 cm) long scrap of 2 by 4 inch (5 x 10 cm) wood.
- Three medium-sized Phillips head (cross groove) wood screws, about three quarters of an inch (19 mm) long.
- A piece of corrugated cardboard about a foot (0.3 m) square.
- A sheet of paper.
- Scotch tape and any type of glue.
- 300 feet (91 m) of 24 AWG enamel coated magnet

wire (a very inexpensive vendor is Electronix Express).

- Four ferrite magnets, about 1.75 by 1.0 by 0.25 inches (44 x 25 x 6 mm). They must have poles on their faces. The ones used in this article are part number 99MAG1875 from Electronix Express, but virtually the same ones can be obtained from Radio Shack. (Note: people using pacemakers should not handle magnets.)
- Scissors, ruler, screwdriver, and pliers.
- A digital multimeter that can measure AC millivolts is useful for tuning and testing the alternator, and for displaying the amount of electricity produced.
- One 1.5 volt, 25 milliamp miniature incandescent lamp. These “mini-lamps” are available from Radio Shack.

You can obtain kits with the materials you need from the Web site (see Access), and download templates and step-by-step photographs of this project for more detail. If you use different magnets or wire than those specified, your output will vary, and you may need to adjust slightly from the plans presented here because of size differences.

Figure 1: Base & Yoke Assembly



Building PicoTurbine

Step 1—The Axle and Yoke

There is a common axle used by both the blade assembly and the alternator, made from a pencil. The pencil point rests in the center groove of a Phillips head screw, and the eraser end is held by a wire loop (see Figure 1).

To make the base and yoke assembly, start with the heavy, 2 foot (0.6 m) section of wire. Using pliers, bend a small loop on one end. Bend the loop so it forms a 90 degree angle with the rest of the wire. Measure 6 inches (15 cm) up from the loop and make a 90 degree bend in the wire. Measure 3 inches (7.6 cm) from this bend and form another loop, slightly larger than the diameter of a pencil. Measure 3 inches (7.6 cm) from the center of this loop and make another 90 degree bend, forming a large square U shape with the wire. Measure 6 inches (15 cm) from this bend, and form another loop. Clip off any excess wire. This U-shaped piece of wire is the yoke.

Fasten the yoke to the wooden base using two screws. The legs of the wire yoke should be centered on the wide face of the wood as shown in Figure 1. Insert the pencil in the center hole of the yoke and rest the point in the groove of the center screw. The pencil should stand as near vertical as possible. Adjust the yoke by bending the wire if necessary to make the pencil vertical both side to side and front to back. Make sure the pencil turns freely in the yoke’s center loop. If you wish, you can put a drop of any type of oil on the screw to make the pencil turn more freely.

Step 2—The Alternator

An alternator is little more than magnets moving relative to wire loops. The magnetic flux density changes as the magnets (or wire) move around, inducing an electric current in the wire. In PicoTurbine, the magnets will spin on an assembly called the rotor, while the wires will remain motionless on a part called the stator (see Figures 2 and 3).

Building the alternator is by far the most challenging part of this project. If you build it carefully, you can achieve about 200 milliamps of electricity at about 1.5 volts in a 20 mile per hour (9 m/s) wind. This is almost one-third of a watt of power.

Step 2A—The Permanent Magnet Rotor

Cut out two pieces of 4 inch (10 cm) square cardboard. Glue them together, forming a double-thick piece, as the rotor will be under a lot of stress. If you are using the templates from the Web site, glue the rotor template to this double piece of cardboard, and after it dries, cut it out. Otherwise, cut a circle out of the double cardboard 4 inches (10 cm) in diameter.

Figure 2: Rotor Template

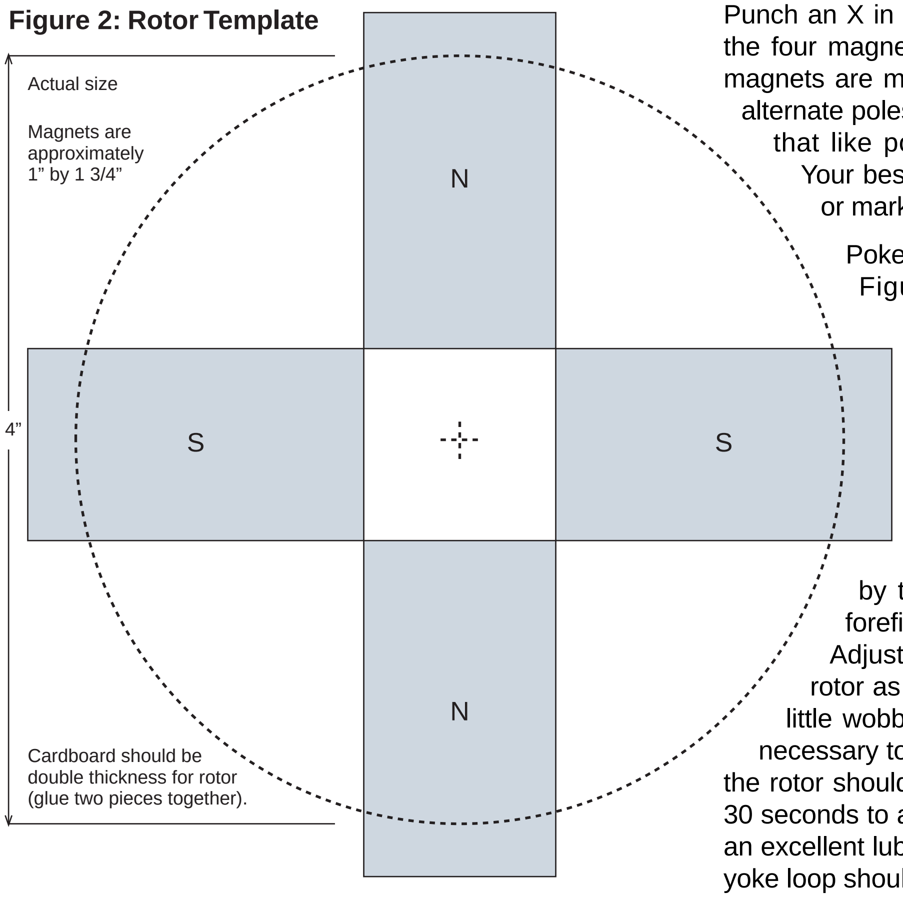
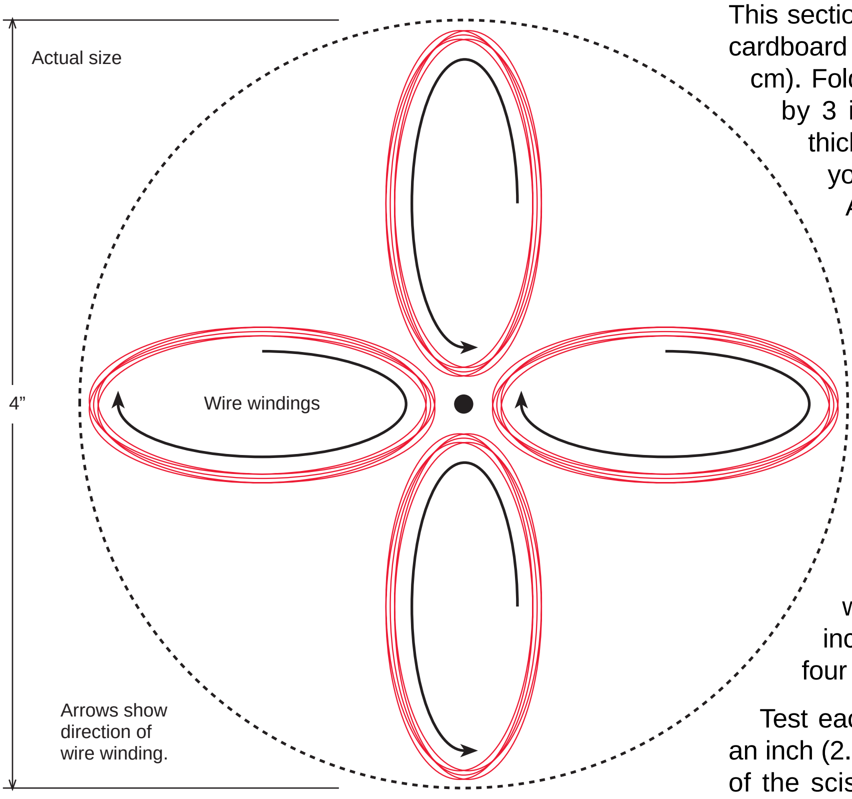


Figure 3: Stator Template



Punch an X in the exact center with the scissors. Tape the four magnets as shown in Figure 2. Note that the magnets are magnetized on their faces, and you must alternate poles going around the diameter. Remember that like poles repel, and opposite poles attract. Your best bet is to mark the poles using a pencil or marker before beginning.

Poke the pencil through the rotor as shown in Figure 6, being careful not to break the point. Work it down slowly so as not to stretch the hole bigger than needed—it must be quite tight. Use some tape to make sure it's a tight fit.

With eraser end up, slip the pencil from the bottom into the yoke loop, pull it through, and lower the point into the center screw. Spin the rotor by twisting the eraser between thumb and forefinger. It should spin freely and vertically. Adjust the wire yoke if necessary. Watch the rotor as it spins—it should rotate evenly, with as little wobble as possible. Adjust it and use tape if necessary to fix it in place. If you give it a good twist, the rotor should spin on its own for quite a long time—30 seconds to a minute. The graphite tip of the pencil is an excellent lubricant and there is very little friction. The yoke loop should not be too tight around the pencil.

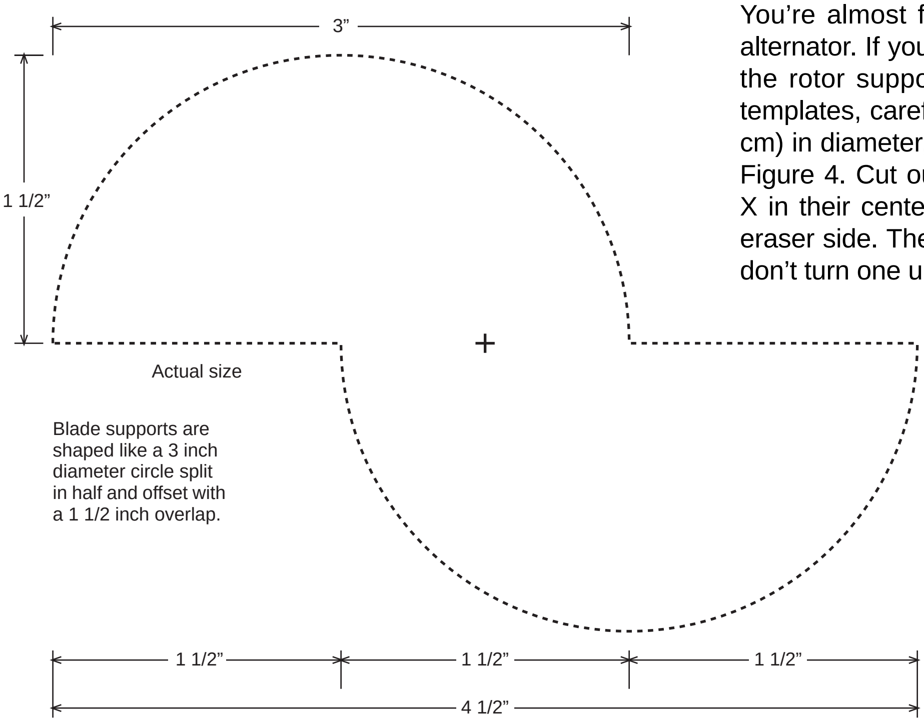
Step 2B—The Wire Loop Stator

This section requires care and patience. Cut a piece of cardboard 1.5 inches wide by 6 inches long (3.8 x 15 cm). Fold it in half to make a piece about 1.5 inches by 3 inches (3.8 x 7.6 cm), double the original thickness. Tape this together so it holds. This is your wire wrapping tool. Take your spool of 24 AWG wire. Leave a tail about 4 inches (10 cm) long and start wrapping loops around the 1.5 inch (3.8 cm) dimension of the cardboard.

Make at least 250 turns of wire around your cardboard wrapping tool. Leave 4 inches of wire (10 cm) after the last turn. Carefully slide the wire off the tool, and immediately wrap tape tightly around the bundle of wire so it doesn't spring apart. The tighter you can form the bundle, the better. You will have a slightly oblong coil of wire, about 2 inches (5 cm) long by about 1 inch (2.5 cm) wide. Do this four times, creating four coils.

Test each coil to make sure it functions. Strip about an inch (2.5 cm) of wire from each end, using one blade of the scissors or sandpaper. Hook to the leads of a

Figure 4: Rotor Support Template



multimeter. Set the multimeter for AC millivolts. Holding the coil close under the magnet section of the axle/rotor assembly, give the rotor a good spin. If you spin it hard and hold the coil close to the magnets, you should see 250 to 300 millivolts or more.

If you are using the templates, glue the stator template to a piece of cardboard and cut it out. Otherwise, cut a 4 inch (10 cm) circular piece of cardboard. Affix the coils as shown in Figure 3. Note that the coils should alternate between clockwise and counterclockwise rotation. Twist together the stripped wires from one coil to the next—you’re wiring them in series. Leave the final two wires (the first and last) unattached. Tape the coils to the stator cardboard. They should lie very flat.

Cut a circle in the center of the stator cardboard. Remove the rotor/axle assembly by pulling up on the eraser and angling it out. Put the stator assembly over the center screw, and tape it down firmly. It will overhang the ends of the wood slightly in front and back. Put the rotor/axle back on. The gap between the coils and magnets should be as small as possible (about 1/4 to 3/8 inch, or 6-8 mm), but not so little that there is any chance of the magnets crashing into the coils when you spin them. Adjust the center screw to change the height of the rotor magnets over the wire.

Now, hook the two remaining wires to your multimeter and give the rotor a spin. If you spin fast, and everything is aligned well, you should get about 1.2 to 1.5 volts (or more, if you’ve built very well).

Step 3—The Blade Assembly
You’re almost finished! This is easy compared to the alternator. If you have the templates, glue two copies of the rotor support to cardboard. If you don’t have the templates, carefully draw two semi-circles 3 inches (7.6 cm) in diameter, shifted 1 1/2 inch (3.8 cm) as shown in Figure 4. Cut out the two blade supports, and poke an X in their centers. Slide them onto the pencil from the eraser side. They should be aligned with each other, so don’t turn one upside down accidentally.

If you have the templates, cut out the blades. Otherwise, cut two pieces of paper as shown in Figure 5. Cut the top and the bottom into 1/2 inch (13 mm) strips, “feathering” the paper. Glue each paper blade on the circular side of the blade support, both top and bottom. Use the feathered edges to negotiate around the circular support.

The final effect is like taking an oil drum, cutting it lengthwise, and offsetting the two halves horizontally before fastening them back together. Put tape along the two leading edges, and tape over the glued top and bottom parts, just for good luck in high winds.

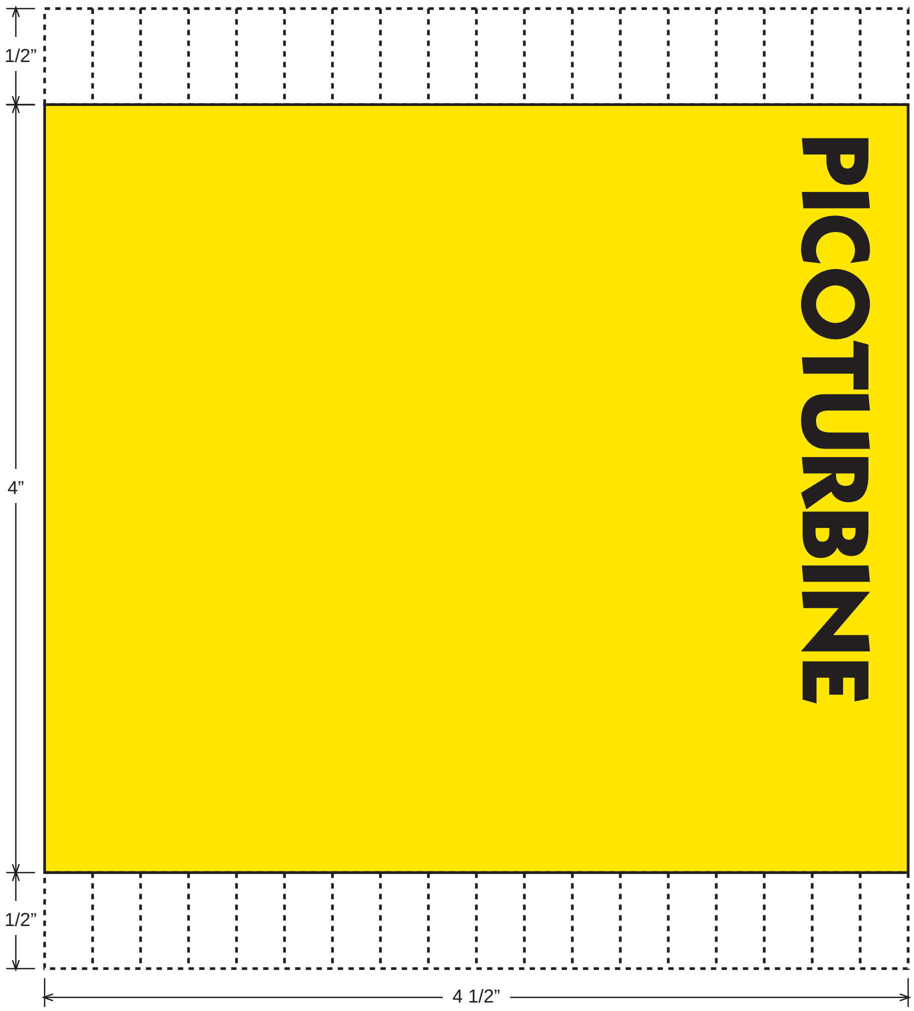
Step 4—Testing
Carefully insert the blade/rotor/axle assembly back into the yoke and set it down into the center screw. Blow into the blades from any direction, and they should start up very easily. Short, puffing blows are best. Hook up your multimeter and blow again. If you have very good lungs, you’ll get a couple of hundred millivolts. The wind will do much better than you can do! For classroom demonstrations, a small fan can provide the wind. Finally, if it’s a windy day, give it a real test using Mother Nature.

Hook the mini-lamp up to the alternator leads, twisting tightly to make a good connection. When PicoTurbine spins about four to five revolutions per second, it will glow dimly. It will be quite bright at ten to fifteen revs per second.

Conclusions and Future Work
PicoTurbine is a small, easily constructed, fully functioning wind turbine. It was designed for ease of construction and low cost of materials so it could be used for educational purposes. Building PicoTurbine is a great way to learn about wind energy concepts and engineering design tradeoffs.

I am undertaking several related projects, including plans for a simple weatherproof version of PicoTurbine, and other design improvements. A version with a three-

Figure 5: Rotor Covering Template



Cut on the dotted lines. Feather the ends to make gluing to the rounded blade supports easier. Make two.

Actual size

phase alternator and a scaled-up design that produces about 5 watts for school group projects are also in the works.

Check the Web site to get up-to-date information on these projects and to see more pictures and design alternatives to the model presented in this article. Ideas for classroom use, educational experiments, and projects that use PicoTurbine are also available, free of charge, for personal and educational use.

If you have any comments, corrections, or suggestions for improvements, you may send them by email to comments@PicoTurbine.com.

The Savonius Turbine Controversy

PicoTurbine is a vertical axis wind turbine—VAWT for short. More specifically, it is a Savonius design, named after its inventor, S. I. Savonius, who patented it in the 1920s. There has been much controversy surrounding the Savonius design, as compared to the traditional, horizontal axis wind turbine (HAWT) for electricity production.

The Savonius design is based primarily on drag (like a cup anemometer). Most commercial electric generating wind turbines use lift (like an airplane wing) instead, and sport the traditional horizontal axis. There are advantages and disadvantages to both designs.

Keep It Simple

The chief advantage of the Savonius is simplicity, as is amply demonstrated by PicoTurbine. Because the design is vertical, it doesn’t need a yaw mechanism to keep it turned into the wind. In fact, PicoTurbine has only one moving part, whereas the simplest small horizontal designs have at least three. In theory, this means that Savonius designs could be built more cheaply and should be more reliable than the more complex horizontal designs.

Everyone’s a Critic

Critics of the Savonius focus on its drawbacks. For one, the academics don’t like drag-based designs because they are not as efficient at converting wind energy to mechanical energy. A good lift-based design can be about 40 percent efficient. There are reports of the Savonius achieving nearly 30 percent efficiency under controlled conditions. In practice, these machines perform at around 15 percent.

The second major criticism centers on how fast the Savonius design revolves. A drag design cannot exceed about a 1 to 1 tip speed to wind speed ratio. Basically, if you look at the speed that the outer edge of the blade travels, it can’t go much faster than the wind speed. A large 3 yard (2.75 m) wide Savonius would spin at a leisurely one revolution per second. In contrast, lift-based designs can achieve a tip to wind speed ratio between 6 to 1 and 11 to 1.

Whither, Savonius?

These drawbacks have given the Savonius a reputation as a design of little practical use for electricity production. One prominent wind technology Web page

implies that its slow speed is an insurmountable Achilles' heel. The authors say that although it could be made usable with a gearbox, that would increase the startup inertia and decrease efficiency further. Another online article says the Savonius is flat-out useless for power generation, and jokes that its main use is to take up space in the garages of would-be inventors!

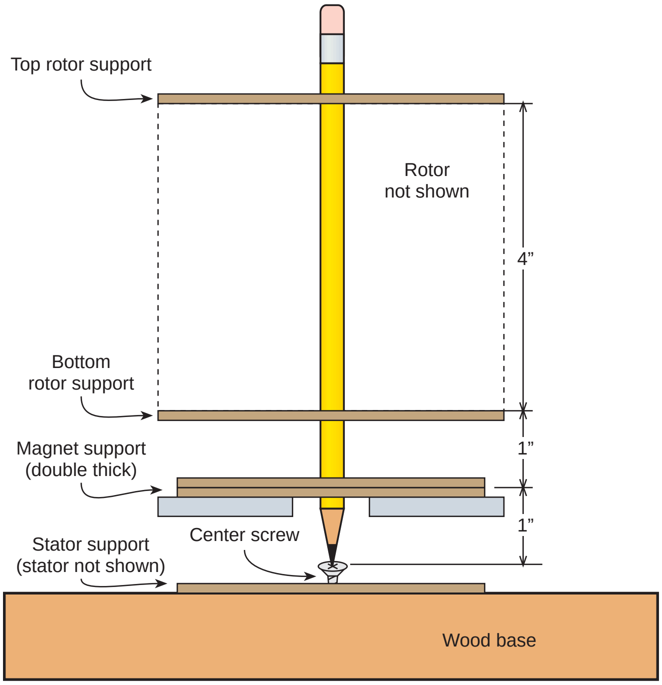
While there is certainly some truth to these criticisms, I believe them to be somewhat overstated. On closer examination, we'll find that the Savonius—while certainly not the choice for commercial power production—could indeed have a niche in the small home system category. I have seen at least one example of a small commercial trickle charger based on the Savonius design.

The Whole Efficiency Story

Like most things in life, the matter of efficiency is more subtle than simply saying that the Savonius is 15 percent efficient and thus inherently inferior to the horizontal design's 40 percent efficiency. The efficiency difference is partly mediated by the fact that a Savonius does not lose efficiency while yawing into the wind. It doesn't care what direction the wind comes from—it's perfectly happy with gusty, shifting, inconstant winds that drive horizontal machines nuts. Paul Gipe, a noted wind turbine expert, estimates this loss at about three percent in his book, *Wind Power for Home and Business.*

In addition, the Savonius sweeps a rectangular section of wind, while a horizontal design sweeps a smaller,

Figure 6: Rotor, Magnet, & Stator Assembly



The finished PicoTurbine ready to spin.

circular area. For example, a 2 yard wide by 2 yard tall (1.8 x 1.8 m) Savonius sweeps 4 square yards (3.3 m^2) of wind, while a horizontal turbine 2 yards (1.8 m) in diameter only sweeps a tad over 3 square yards (2.5 m^2).

The power output of any wind turbine is directly proportional to its swept area. When it comes to the space needed for installation, the circular sweep takes up just as much room—you can hardly claim to be able to do anything with the space "saved" due to the corners being rounded off!

After taking into account these factors, the Savonius is still at a significant efficiency disadvantage versus a good horizontal design, making it unsuitable for large-scale electricity production. However, the ease of construction and low wear and tear design offsets much of this disadvantage when the application is small-scale electricity production, especially of the homebrew variety. If the Savonius is a few percent less efficient, then simply make the blades a few percent taller—problem solved.

It's the Alternator, Stupid!

Now let's discuss the rotation speed issue. It is true that many attempts at building a homebrew Savonius generator fail. Consider a popular formula for a Savonius windmill that I actually found on the Web:

- Take a 55 gallon oil drum. Cut it in half lengthwise, and weld the parts into the offset Savonius shape.

- Affix this contraption to an old car axle welded to the shaft of a junked car alternator.
- Voila! You have just made a wind turbine.

Unfortunately, even in a gale this thing is unlikely to make a 10 watt light bulb glow. Many people blame such failures on the Savonius design. In reality, the problem is not the wind turbine—it's the alternator!

Alternators For Dummies

Let's talk alternator physics. (It won't hurt, I promise!) As we learned from PicoTurbine, an alternator is basically just some wire loops in motion relative to some magnets. The power produced depends on several factors: how strong the magnets are, how many loops of wire, how thick the wire is, how fast the magnets move, etc. Now, here's an important point: by varying these design parameters, you can make an alternator that produces any arbitrary amount of power at any speed you choose to optimize for.

The power output varies with the square of the speed. If you run an alternator at half its design speed, the power is cut by a factor of four, not just two. So, let's say our intrepid homebrewer tries to use a car alternator designed to turn at 30 revs per second on a barrel Savonius that only turns 3 revs per second. That's 10 times slower than the design speed, so power will be cut by 10 squared—a factor of 100! If that alternator were designed to output 100 watts, our homebrewer will get a paltry 1 watt output. (He would get the same wattage from the high power model of PicoTurbine!) The result is predictable—another Savonius taking up the corner of a garage.

Alternative Alternator

By increasing the number or strength of magnets and/or the thickness and number of loops of wire, we can in fact make an alternator that produces 100 watts (or any other power) at 3 revs per second (or any other speed). But that alternator will bear little resemblance to one designed for a car. For one thing, it will likely be much larger to accommodate more magnets and thicker wire. This is no big problem—there's plenty of room below the Savonius blades for a large alternator.

Cheers for Magnets, Jeers for Gears

And, just to dispel one final myth, there is no compelling reason why we must use physical gears to increase shaft speed. We can in effect "gear up" the speed using more magnetic pole changes per revolution. The wire loops only care how many pole changes they "see" per second. They can't tell the difference between two magnets flying by ten times per second and ten magnets flying by two times per second.

PicoTurbine uses four magnets to cause two north-to-south pole changes per revolution. This is equivalent to using a 2 to 1 gear ratio—but without the friction losses and other headaches of physical gears. This concept can be extended to any ratio desired by simply adding more and more magnets to the design.

Access

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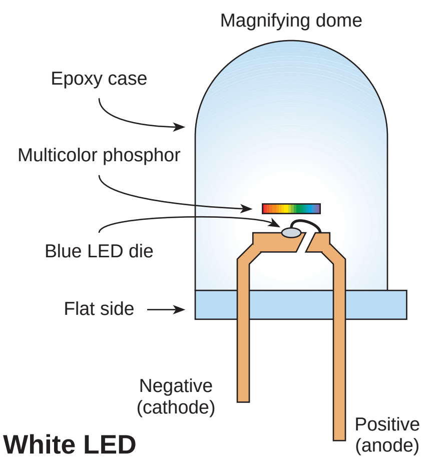
Many thanks to electrical engineer Randal B. Elliot of Portland, Oregon, for verifying the technical accuracy of this article.

White LED Enlightenment

Ed Lillis and Jon Tiedemann



White LED

For low wattage lighting, LEDs (light emitting diodes) are the most efficient devices for converting electric power to light. Until recently, they have only been available in colors. Now we have white LEDs, so let's start using them! We'd like to share some homebrews we're using. Maybe they will give you some ideas to play with.

The white LED is made by shining a high brightness blue LED on phosphors. This creates a very clean even pattern due to the large emitting area.

Camp Light

I built my lamp on a piece of circuit board the same size as the top of a 9 volt (7.2 volt in NiCd) battery, so it plugs in right on top. With a fully charged battery, it gives full light output for four to five hours and then gradually dims. Due to the nature of diodes, the battery can only drop to 5.2 volts [2.5 (LED) + 2.5 (LED) + 0.2 (regulator)]. This provides a rudimentary low voltage cut-out.

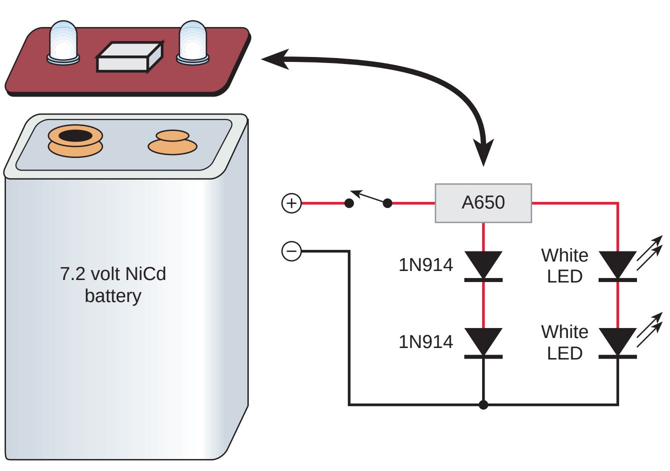
The A650 is a 5 volt low-dropout voltage regulator. 1N914s are temperature compensation diodes and should be positioned against the white LEDs. They also raise the voltage to 6.2 volts. If you refer to the IV curve, that gives you 25 milliamps (mA), which is within safe operating range.

Bright Light

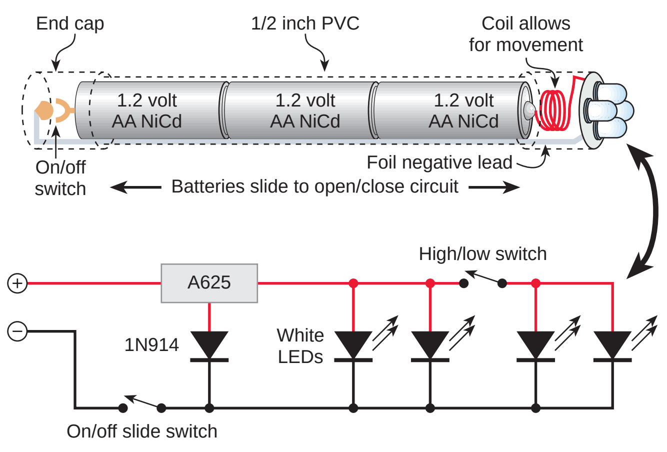
This one uses three 100 milliamp-hour AA NiCds that fit nicely into 1/2 inch (13 mm) PVC pipe. The end cap can be drilled to accept the LEDs and switch(es). With four LEDs in the circuit, you get fourteen hours of light per charge. The quantity and quality of light output is superior to any other unit of comparable weight and size. The light has an evenly dispersed quality, with color and temperature similar to daylight fluorescent tubes.

I soldered the batteries together and shrinkwrapped them as a unit. The LED end of the pipe contains the circuit and a coiled wire that attaches to the positive side of the battery pack. The purpose of the coiled wire is to keep it from fatiguing, since the switching is done by sliding the battery pack inside the pipe. I ran a piece of copper foil inside the pipe to make the negative connection. At the negative end of the pipe, there is a mushroom shaped post connected to the foil. On the negative end of the battery pack, I soldered a fuse clip "U" that mates with the mushroom-shaped post.

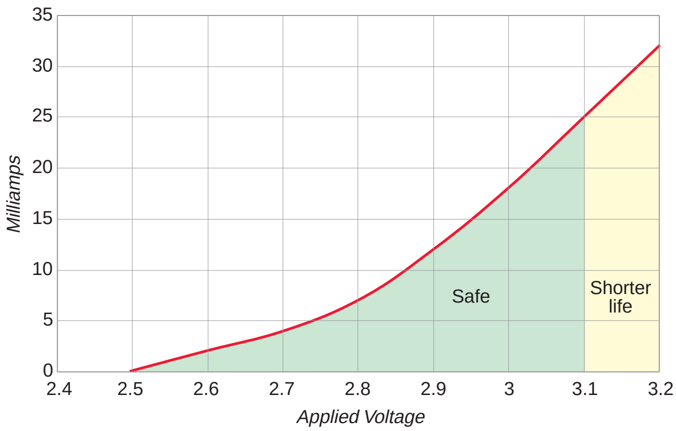
Camp Light



Bright Light



White LED IV Curve

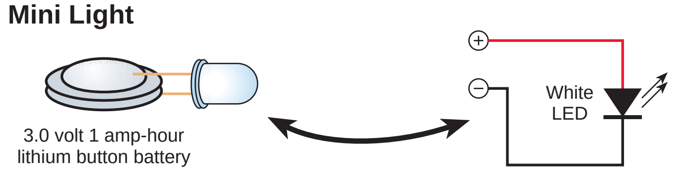


To switch it, whack the negative end for *on* and the LED end for *off.* An additional advantage to this "inertial" switch design is that the unit can be waterproofed. A disadvantage is that if you drop it, it will turn on or off depending on which end hits the ground. To recharge, connect copper foil contacts which fit nicely between the pipe and the end caps.

Mini Light

A 3 volt, 1 amp-hour lithium battery and a white LED make a good impedance match. Just tape the LED leads to the sides of the battery. The LED behaves like a 15 ohm resistor in series with a 2.7 V voltage drop. The battery has an output impedance of 15 ohms and the combo will last 100 hours at 7 to 10 mA.

Mini Light



Access

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Watt—unit of power, rate of energy use or flow

Ian Woofenden

Derivation: The watt as a unit was originally proposed in 1882. It was named after James Watt, who invented an improved steam engine.

If I ran the circus, I might rename the watt. This isn't because I have anything against James. But a watt, like an amp, is a *rate,* while neither term *sounds* like a rate. A watt is technically a joule per second, a specific amount of work done in a specific amount of time. Because the term doesn't sound like a rate, it's easy to slip into thinking it's a quantity of "stuff"—of electricity or of energy.

A watt in itself doesn't tell us how much energy is being used, only how quickly it is being used. A 100 watt light bulb uses energy twice as fast as a 50 watt bulb. But saying that you "used 50 watts" is about like saying you "took a 50 mph trip." Unless you tell us how many hours your trip took or how many hours you ran the electrical load, we can't figure out how far you traveled or how much energy you used. Think of the watt as an instantaneous measurement, like the cop catching you at 75 mph with his radar gun.

To calculate watts (joules per second), multiply amps (coulombs per second) times volts. A renewable energy (RE) system with a voltage (electrical "pressure") of 24 volts and a load drawing 3 amps (rate of electron flow) will be delivering energy at the rate of 72 joules per second, which we call 72 watts. The formula is *amps x volts = watts.* It can be reversed to calculate amperage when only watts and volts are known, or to calculate voltage when only watts and amps are known.

Since a watt includes voltage, it is a measure that allows comparisons regardless of system voltage. A 100 watt 12 volt DC bulb is using energy at the same rate as a 100 watt 120 volt AC bulb. With traditional incandescent light bulbs, we grew up seeing a watt as a measure of light output and we compared the brightness of different bulbs by their watt rating. With the advent of super-efficient compact fluorescent light bulbs, these comparisons are no longer valid. A modern 15 watt compact fluorescent puts out about the same amount of light as a 50 watt incandescent bulb. This can remind us of two things: that a watt actually tells us the rate of energy use, *and* that we should buy compact fluorescents!

To get to the ultimate measure of energy use in our RE system, we have to add *time* to the equation, which I'll do in my next column when I talk about *watt-hours.*

Access

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EV Tech Talk

Mike Brown

It's spring and there is new activity among EV enthusiasts, as with other life forms. For those in warm climates, the winter project EV is about ready to hit the road under its own power. In cold places, those EV tinkerers are starting to think about their summer projects.

"I am interested in converting a gas car to electric power and I noticed that your universal kits don't include a motor mount. Why is this, and how do I design a motor mount for my car?"

This question came by email the other day. The answer to the first part of the question is easy. Each car that could possibly be converted has a different way of mounting the internal combustion (IC) engine, so a good universal one-size-fits-all mount is not possible. A motor mount that tries to fit everything won't fit anything very well.

Designing a mount from photographs and drawings is difficult, and can only be as accurate as the drawings. I tried it once for a guy with an oddball motor. About the time I had finished the design, he told me that the outside diameter of the motor was about one eighth of an inch (3 mm) less than he had told me at the start of the project. Even with a computer and a CAD program, the correction took some time. Another time, a factory drawing of a motor proved not to match the actual motor sitting on my workbench. So it is up to individual converters to design their own motor mounts.

Measure First, Then Disassemble

Motor mount design begins before the IC engine is removed. If the car is a front engine/rear wheel drive car, a measurement is taken from the top of the transmission bellhousing to a seam or mark on the firewall. Having this dimension allows you to place the electric motor/transmission assembly in the same position as the IC engine/transmission assembly you removed. This is important for shift linkage operation and drive shaft or constant velocity joint angularity (the angle of the driveshaft or constant velocity joint from horizontal). Both of these things can cause difficulties further down the road if they aren't addressed properly at the beginning.

If you have a front engine/front wheel drive car with the engine mounted in the transverse or side-to-side position, get a straight piece of wood or metal that will go across the engine compartment above the transmission. Position this straightedge directly above the top of the transmission bellhousing, and mark where the straightedge rests on the fender or hood recess so you can put it in the same place later. Measure the distance from the top of the bellhousing to the top or bottom of the straightedge.

Check For Damage

As you remove the IC engine, pay attention to the motor mounts that hold the engine in the car. These are usually pieces of hard rubber bonded to metal so that they can be fastened to the chassis and engine. Living as close to the engine as they do, there is a possibility of damage from oil leaks and heat. The rubber will be sticky to the touch and mushy when force is applied if it is oil soaked. If there is heat damage, it will be blistered, hard, and brittle. Make sure that there are no tears in the rubber and no separation where the rubber is bonded to the metal.

Unless they are totally destroyed or collapsed, damaged mounts can still be used at least for the design phase of your motor mount. If the design you develop can use the original style of mounts, but yours are in poor condition, buy new ones when you are ready to start assembly.

Install The Motor

Before we go any further, I'd like to add a word of caution. On all motors, there are four sets of two or three bolt heads in a row spaced 90 degrees apart on the motor case. These bolts hold the field coils to the motor case. Under no circumstances are these bolts to be removed and their holes used to hold part of the motor mount. Even loosening the bolts may result in motor damage.

Now the actual design work begins. Install the adaptor, flywheel, and clutch on the motor, and bolt that assembly to the transmission. Check the rubber/metal transmission mount for condition as you did with the motor mounts, and replace it if necessary. Hoist the motor/transmission assembly into the car. When it's in position, fasten the transmission mount to its place on the chassis.

The transmission mount gives us a point from which to start the motor mount design, as it locates the assembly fore-and-aft and side-to-side, as well as vertically at one end. If the mounting hole on either the transmission or the chassis is slotted, look for marks that indicate where it was in its previous life and fasten it there.

At this point, I support the other end of the motor with a floor jack. Engine hoists are difficult to work around, and can be expensive if they are rented by the day. This mount design stage can take some time. Using the jack, raise or lower the motor until you duplicate the measurement you took from the straightedge at the start of the design process.

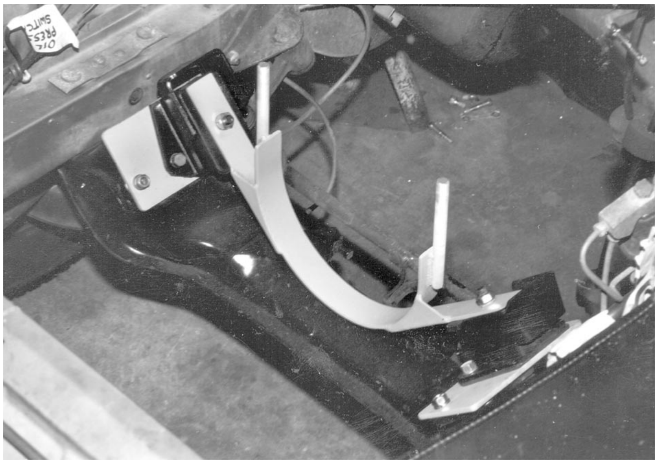
Now the motor can be held in place with wood blocks between it and a crossmember, if there is one in a suitable location. On a front wheel drive car, the motor can be suspended with a chain from the straightedge if it is strong enough. The purpose of using the wood blocks or chain is to get the floor jack out of the way. This is handy if the car has to be moved for some reason. However you hold the motor in place, be sure to maintain the transmission height at the measurement taken earlier.

Rear Wheel Drive Design

Now we are going to focus on the motor mount design for a front engine/rear wheel drive car or truck. Since most converted passenger cars are front wheel drive, this section applies mostly to light trucks. This type of mount is often called a "cradle mount." It consists of a U-shaped steel strap bent to fit around the outside diameter of the motor, and another smaller piece of strap that bolts to the top of the U-strap to clamp it in place. The purpose of this mount is to locate the motor end of the motor/transmission assembly both vertically and side-to-side in the car or truck. The strap should be no less than 3/16 of an inch (5 mm) thick and no less than 1 1/2 inches (38 mm) wide.

Next, bolt the original rubber/metal motor mounts to the chassis. The gap between the rubber/metal mount and U-strap around the motor is what you have to fill. This can be done with another pair of straps which will bolt to the rubber/metal mount on one end, and will be welded to the U-strap on the other end. The bolt end of each chassis strap may have to be angled to match up to the face of the rubber/metal mount.

A cradle-type motor mount for a front engine/ rear wheel drive car.



Once you have the strap design worked out, it is important to make flat triangular plates to weld across the angle where the motor straps meet the chassis straps. These plates are called gussets, and they will make the mount stronger and prevent bending and twisting.

Making It Fit

I have found it very helpful to use cardboard or foamcore artboard to make a mock-up of the mount. Another place where a mock-up can help is checking for interference between the mount and things like motor terminals or the heads of the motor field bolts I mentioned earlier.

Sometimes a fitting problem can be eliminated by offsetting a hole in the strap a little. Another trick is to use a steel spacer plate to offset the rubber/metal mount a little forward or backward from its original position on the chassis. Also, be sure that no part of the mount assembly projects into the space where you are planning to put battery racks and boxes later.

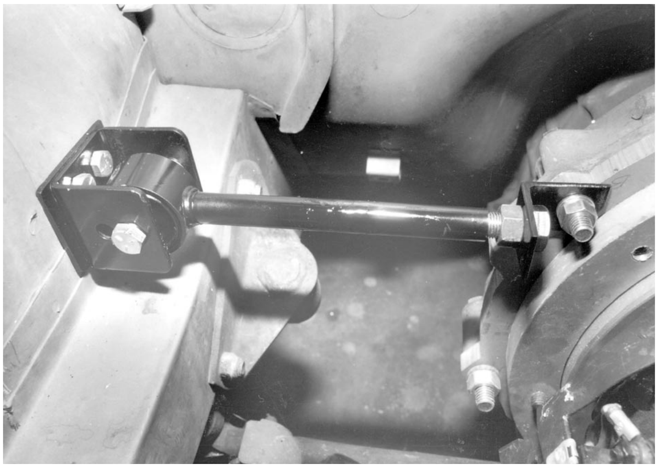
When all of these issues have been resolved, measure the parts of the mock-up and make drawings for yourself or the welder who will fabricate the mount. It doesn't hurt to show your welder the mock-up as well.

The cradle mount system is the easiest one to use in front engine/rear wheel drive cars or trucks. It uses existing parts and doesn't require any welding on the chassis. Ninety percent of the rear wheel drive cars and trucks suitable for conversion will work with the motor mount we have just described. If you have a vehicle that won't work, call or email me and we'll talk about it.

Torque Control

As I said earlier, the purpose of this mount is to locate the motor vertically and side-to-side in the car or truck. The motor case must also be prevented from rotating around the armature when it is in the nearly locked armature condition that occurs during a standing start. The best fitting cradle mount, tightened as tight as possible, will not stop the motor case from rotating under these conditions. Even if you could fasten the cradle mount directly to the motor, IC engine mounts are not designed for this kind of load and will stretch enough to cause problems.

The solution to this problem is a torque rod. This is a rod or bracket that goes between the chassis and the motor/transmission assembly to prevent rotation. I like to use a torque rod from a 1975-1979 Honda Civic. It looks like a dog bone with a rubber bushing at each



A Honda torque rod, adapted for use in an electric car.

end. One of the bushings and its holder unscrew from the rod, leaving a handy threaded hole you can use to fasten a bracket between the rod and the motor or adaptor. The bushing end of the rod then mounts to the chassis and holds the motor in place.

The torque rod can go between the motor and the chassis, or between the adaptor and the chassis. It can act in tension or compression, so it can be mounted where it is least in the way. The use of one rubber bushed end is recommended to isolate the chassis from drive train vibrations.

Front Wheel Drive Design

Now we'll look at the front engine/front wheel drive cars, which most modern conversions are based on. The good news is that the engine/transmission packages are pretty sophisticated, with good locating systems, usually two transmission mounts, and torque control already built in. The bad news is that the engine compartments are small, so mount design can get tricky. Also, the cars are of unibody construction, so bolting and welding things to the chassis must be done carefully.

Most of these cars have two transmission mounts, and at least one of them bolts directly to the transmission. In some cars, the bolts holding one of the mounts go through the engine block and then into the transmission. In this case, the original bolts can be used along with washers or machined spacers to make up the difference between the thickness of the engine block and the adaptor plate. If this needs to be done in your car, do it before the next step.

Lower the motor/transmission assembly into the car and attach the transmission mounts to the chassis. Support the motor with a floor jack or a chain to the straightedge as I described for rear wheel drive cars. Duplicate the transmission height measurement taken earlier.

Now we can design the motor mount. Again, it is best to use as much from the original mount system as possible. Bolt the factory engine mount into position and see if an arrangement of plates and straps will fill the gap. How easily this is accomplished depends a lot on the brand of motor you are using. The popular Advanced DC motors have threaded holes on the brush end of the motor for mount bolts. The older GE and Prestolite motors have no such holes, so a clamp similar to the cradle mount described above must be worked into the mount design.

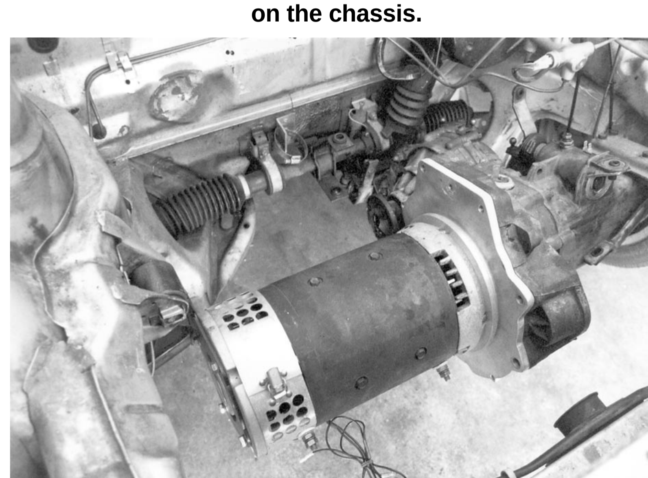
Sometimes there is no way to use any of the original mount in your design. In that case, design the part that attaches to the motor, make your drawings, and have it built. With that in place, design and fabricate the mating parts that have to be welded to the chassis. Bolt everything together where it belongs and tack weld the chassis parts to the car. Then take everything apart and make permanent welds.

Welders & Bushings

If you are doing your own welding, this is easy. If not, you might pick a welder who can come to you for the chassis welding. But you should still have everything else done at the welder's shop, as mobile rates are usually higher. I had one conversion towed to my welder's shop, where I installed the motor and then had him do the rest of the mount fabrication. The tows there and back to my shop cost a bit, but the results were worth it.

A word about rubber bushings. If you use the factory rubber bushings or mounts in their original position with the loads applied in the same direction, you should be

In this front wheel drive car, the motor mount bolts to the end of the motor and to the original brackets on the chassis.



all right. On the VW Rabbit, the engine mount bushing is round, and the hole through it for the bolt to the chassis is off-center. There is an arrow and the word “Up” molded into the rubber. This bushing only works in one orientation.

If I had used the original part in my mount, it would have been turned with the arrow pointing to one side, which would not have worked. Instead, I ended up using a GM rear control arm bushing (Moog #K6178), which was the right length, had the right bolt hole size, and was heavier duty as well. Most of the time, a search through the catalogs at a good parts house will provide you with what you need for a suitable substitution.

On front wheel drive cars, the torque rod issue is usually dealt with by the factory, as too much movement front-to-back would have an adverse effect on the gear shift and throttle linkages. Here’s a good rule to follow: if there is a torque rod in the original engine mount system, then you should use it or something like it in your motor mount system. The factory torque rod will probably work in your application with little or no modification.

Mission Accomplished

Now you should have an idea of what is involved in designing a motor mount for your conversion. I hope I haven’t scared anybody off. If you want to skip the whole mount design part of a conversion, convert an aircooled VW Bug. The motor can just hang off the transmission without a mount, like the gas engine did. These transmissions had three mounts, which were capable of supporting the engine as well as the transmission.

These are some general thoughts about motor mount design. If you have a specific question or problem, feel free to phone or email me and I’ll try to help.

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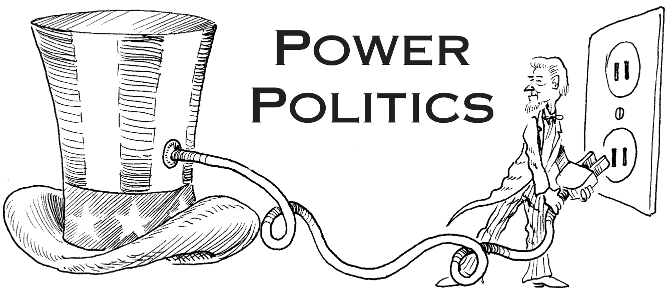

Don't Waste America

Michael Welch

The Achilles heel of nuclear power is nuclear waste. National anti-nuclear groups are concerned with its transportation as much as with the waste storage itself. So when it comes to community organizing, one major focus is educating the public about nuclear waste transportation.

Bills are in both houses of Congress that would force Nevada to become our nation's repository of commercial nuclear waste. If these bills pass and are signed by the President, communities in transportation corridors would be exposed to the dangers of high-level nuclear waste. It could also help usher in a new era of nuclear power plant construction, help already existing plants to lengthen their operating life past their current licensing, and transfer liability for and ownership of the dangerous waste to our government (in other words, to us). Let's make it clear—there is no known way to safely isolate this waste for the over one million years that it will be dangerous.

According to the Critical Mass Energy Project, if Congress passes HR45, The Nuclear Waste Policy Act of 1999, it will bring nuclear waste within one-half mile (0.8 km) of 50 million Americans in 43 states as it is transported across the country to Nevada and dumped at a temporary site. The Department of Energy's projections for an accident leading to a small release of radioactive material (1,380 curies) in a rural area show that it would contaminate a 42 square mile (109 km^2) area, require 460 days to clean up, and carry a US$620 million price tag for cleanup.

Nobody's Back Yard

The nuclear utility industry still hasn't figured out what to do with its dangerous by-products. They don't seem to be interested in safe, long-term solutions. They just want the problem to go away so they can continue with "business as usual." In fact, the nuclear industry is pushing for any solution they can get, hoping they can begin building their next generation of nuclear reactors.

The problem has no real solution, and the only way to deal with it is to stop making more waste. Anti-nuke activists want utilities to store nuclear waste in their spent fuel pools until they run out of room for more, forcing the plants to shut down.

Nevada has been touted for decades as our country's only possibility for a long-term, high-level nuclear waste repository. As you might imagine, Nevadans have a problem with that. Their efforts and discoveries relative to the chosen Yucca Mountain site have, so far, kept hundreds of thousands of tons of nuke waste from being transported and stored there. The Yucca Mountain site is too problematic to be considered as a repository. There are active faults in the area, and more seepage than is acceptable.

The choice of Yucca Mountain was purely political. Other states that were being considered had too much clout to be contenders. Nevada, with its sparse, rural population, was wrongly perceived by politicians as not having the wherewithal to put up a good fight. Whoops—Nevadans turned out to be very capable of exposing the flaws in the politicians' plans. They even started and funded a state government agency specifically to fight the nuke dump on scientific and grassroots levels.

Nevada Senators Richard Bryan and Harry Reid have combined with that grassroots effort to do a superb job of stopping four years of Congressional effort to open the dump. But like a bad dream, legislation keeps popping up that is designed to end the Yucca Mountain fight by making the site an "interim" nuclear dump. Of course, any interim dump would become a de facto permanent dump. Everybody, even the utilities and nuclear industry, understands that there will probably never be a permanent solution to the problem of high-level nuke waste.

Who Gets Stuck Holding the Bag?

Fortunately, President Clinton has been steadfast in his commitment to veto legislation that proposes interim storage at Yucca Mountain. On the other hand, there seems to be a creeping sentiment in the administration and the Department of Energy that "something must be done." What this means requires serious guesswork, but DOE Secretary Bill Richardson suggested that the DOE could take title and liability for the waste and pay for at-reactor (on-site) storage of it.

Richardson wants to do something to avoid further lawsuits resulting from the government's ill-advised commitment to build some sort of a facility to take the

waste off utilities' hands. Washington, DC's environmental community met with Richardson and let him know that it was unacceptable for our government to take title and liability for the nuclear industry's garbage.

Mobile Chernobyl

The national organizations that deal with this issue have been attempting to involve the citizenry, not just the state of Nevada. The organizing tool is not the dump itself, but the transportation of the waste and the shipping routes through nearly every major metropolitan center. As people find out that dangerous spent fuel may be traveling through their communities, their feelings and action are often heightened to the point that they are willing to help the cause.

It really is dangerous to ship this waste. It has to travel in specially designed casks that are airtight and heavily armored against both radiation leaks and traffic accidents. So far, none of these casks have been subjected to a serious accident. They have survived simulations, but these don't really give a credible test of the most severe possible accident. Imagine the disaster associated with the spillage of plutonium-contaminated fuel rods into our rivers or communities. Hence the moniker, "Mobile Chernobyl."

Pending Legislation

HR45, this year's Mobile Chernobyl legislation, is expected to come out of the House Commerce Committee in May. It is likely to hit the House floor soon after that. There will probably be filibuster attempts, but a vote is predicted for May. The Senate's equivalent bill, SB608, is expected to be pushed through earlier. The passage or failure of these bills is still up in the air.

Congressional representatives are well aware of the President's veto promise, and that can have an effect on the number of votes. On one hand, possible veto adds to the uncertainty because legislators don't like to spend all that time working on a bill just to spin their wheels. On the other hand, legislators who want to avoid the ire of the nuclear power industry can do so safely by voting for the bill and falling back on the probability that a veto will save them from instituting a bad law.

Environmental Justice

There is a growing environmental justice movement in the United States. Studies show that low income and minority communities are more often saddled with environmentally dangerous projects than affluent and middle class neighborhoods. Nuclear waste transportation is a good example of this because Mobile Chernobyl would have a disproportionately high impact on poor communities.

Nearly all the major transportation corridors avoid areas of affluence because the poor have far less influence. The freeways, highways, and train rails used for hazardous materials transportation have been built through predominately poor communities and those with more racial minorities. And when the influential move into cities, they usually avoid the poorer neighborhoods that surround transportation corridors.

Environmental injustice has spurred increased involvement from community leaders who are concerned with racial and social injustice. The unaffected sit back, feeling OK about where they are. But minority community activists have realized that this is another huge inequality, and they are doing something about it. It's getting increasingly difficult to site chemical-related, power, and other polluting plants in minority communities. So it is with Mobile Chernobyl. Activists are finally realizing that environmental injustice is really another social injustice, and they are weighing in on the nuclear waste transportation issue.

Money Becomes an Issue

Funding of nuclear waste storage has also become a major issue. Some House Democrats are unhappy with the way this year's Mobile Chernobyl bill addresses the issue, causing it to lose some support. If a bill for interim storage is passed and funded, there still needs to be money made available for a permanent facility. (Yes, we would get to pay for it twice!) If funds are not included for both interim and permanent facilities, then there is no way legislators can justify calling a dump "interim," since it becomes obvious that it is not. But doubling the price tag is troublesome for a program that is already running a deficit.

The Mobile Chernobyl legislation would put a cap, and later a reduction, on the amount of money that the utilities would pay into the Nuclear Waste Fund. This means that taxpayers, not the nuclear utilities, would be responsible for too much of the cost of nuclear waste disposal. Hey, the utilities and nuclear industry decided to make this garbage without sufficient thought to the consequences, and now they want us to cover their mistakes!

The legislation could still leave the DOE open to more lawsuits from nuclear utilities, which could cause further budget shortfall if lawsuits are successful. Three utilities, all representing closed nuke plants, have successfully sued for damages resulting from the DOE being unable to take their high-level waste by 1998. Monetary damages have not yet been assessed in any of these cases, so the total effect remains to be seen. Those costs could be significant to the DOE, especially if owners of operating nuke plants can also sue successfully.

Help Put the Pressure On

Write letters to Congressmembers and to your local newspaper editors. Mobilize phone trees; if you don't have one, start one. Demand that your state and federal policymakers take a stand for the environment and for public health and safety.

The nuclear industry is trying to portray the Mobile Chernobyl bills (HR45 and SB608) as pro-environment legislation. Don't be fooled, and don't let them fool your Congressmembers. These bills shove nuclear waste down Nevada's throat, and expose poor communities to the dangers of high-level nuclear waste transportation. They would override virtually every environmental and public participation law that effects the Yucca Mountain site. They establish unsafe radiation standards for a permanent dump at Yucca Mountain.

Stick 'Em Up and Action Camps

Nuclear Information and Resource Service (NIRS) has made stickers available to be placed along potential nuke waste transportation routes. They read, "Danger: Radioactive Waste Transport Route. For more information, call your Congressmember, 202-224-3121." They are bright red with a yellow and black radiation symbol. Put them up in your town to speak out against what we hope will be the last Mobile Chernobyl bill.

There will be two camps and a rally this summer to help protest the Mobile Chernobyl bills. The first camp will be August 13-20, in southwest Michigan. The Nuclear Free Great Lakes Action Camp will include rallies, nonviolent action, workshops, trainings, renewable energy exhibits, and fun.

Then on August 20-28, the Nuclear Free Northeast Action Camp will be happening in Dummerston, Vermont. A rally will be held in Brattleboro, Vermont on August 21, and will feature nationally-known speakers and entertainment. There will be nonviolent direct action at the Vermont Yankee nuke plant, workshops, trainings, and lots more. Contact NIRS for more info on these events.

Ward Valley Nuke Dump Finally Dead

A victory! After being in the works for over a decade, the Ward Valley Low Level Nuclear Waste Dump is not going to be built (see *HP40,* page 100 and *HP64,* page 86). Environmental and Native American activists persisted when a U.S. District Judge ruled that U.S. Interior Secretary Bruce Babbitt acted properly in rescinding transfer of the Ward Valley site to the State of California.

The state was bound by law to build the dump if title was transferred. US Ecology, the contractor designated to build and operate the dump, indicated that they would not appeal the ruling. The dump was to have stored nuclear waste in unlined shallow trenches just a few miles from the Colorado River. May the Desert Tortoise and the sacred Mojave lands rest in peace.

WIPP not Whipped

The possibility of the Waste Isolation Pilot Project (WIPP) opening its gates to nuclear waste from weapons production had hung for weeks by a slender thread, according to Betty Ball of the Rocky Mountain Peace and Justice Center of Boulder, Colorado. The thread was snapped on March 24th as a Washington, DC judge dropped an injunction that had been put in place by citizen groups from New Mexico. Activists from Colorado, New Mexico, and your state will participate in direct action against the Department of Energy as they express opposition to the opening of the WIPP facility.

In conclusion, the nuclear menace is still with us, in spite of no nuke plants being built or ordered since the '70s. We look forward to the day when existing plants are shut down so that no more radioactive waste needs to be stored. Renewables are the future of our global energy policy. The nuclear industry hasn't figured that out yet.

Access

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And the Beat Goes On

Don Loweburg

The pace of corporate acquisition within the renewable energy industry continues unabated. In previous columns, we noted the growth of BP Solar and their extensive vertically integrated operations in the United States. More recently, Applied Power Corporation, a subsidiary of the investor-owned utility, Idaho Power, purchased Alternative Energy Engineering.

That purchase follows closely the acquisition of Ascension Technology by Applied Power Corporation. Applied Power's one time competitor, Solar Electric Specialties, is also owned by Idaho Power.

Some would hold that this level of aggregation is a healthy sign, the long awaited "coming of age" for the renewables industry. In these times, it seems to mean corporate consolidation of smaller companies. The end game of this process is the creation of global cartels. That trend is evident in almost all sectors—witness Walmart, Costco, Home Depot, and Monsanto, among many others.

An Ominous Example

The depth of corporate hegemony in some cases is spectacular. Monsanto, for instance, not only produces huge amounts of agricultural chemicals, they also "produce" seeds that are immune to these chemicals. The seeds (soybeans) are genetically engineered and hence are the "intellectual property" of Monsanto. Farmers who use part of their own crop for seed are being cited and sued for patent infringement.

To do business with Monsanto, farmers must agree to buy all their new seed from the corporation. Can we not see how insidious this level of corporate control is? Doesn't the ownership of distributed energy technology by petroleum cartels and investor owned utilities send a signal?

Who Defines the Rules?

Supporters of this global trend generally focus on the need for improved "competitiveness." This, they argue, can be achieved by increasing efficiency. Efficiency can be improved by combining operations, investing in new technology, and cutting overhead (jobs). Since prices don't go down, the benefits of the increased efficiency are realized as increased profits. So, from the point of view of the corporations and their investors, competitiveness equates with profits. But what does competitiveness mean to the consumer?

From the consumer's point of view, "competitiveness" results in fewer manufacturing sources, fewer distributors, and generally less choice in the marketplace. Note how diametrically opposed this result is from that of the theory of naive capitalism—through competition and choice in the marketplace, the best products and services survive and evolve while prices are kept low.

Why Does IPP Care?

My perspective is that corporate mergers are anti-competitive. Mergers generally are about maximizing profit and gaining and controlling market share. The current rally of corporate acquisition in the PV industry is mostly about controlling market share.

What does all this mean for IPP in practical terms? As wholesale purchasers of equipment, we have less choice. Last year, there were four large independent distributors on the West Coast. This year, only one independent (not owned by a utility or petroleum company) distributor remains. There is less competition for our business.

The stage is now set for further control of market share through predatory pricing and control of product availability. Both practices are already evident. Smaller distributors cannot place the million dollar plus purchase orders now routinely going out to manufacturers nor can they match the lower prices offered by the conglomerates (utility or petroleum—take your pick).

Bottom Trolling Revisited

Low prices are a good thing, right? Maybe, but not always. The answer depends on the context. A couple of columns back *(HP69)* I mentioned how retail PV system purchasers might be shooting themselves in the foot when they buy equipment from "box" merchants. In

effect, the dollars spent this way are "votes" against local entrepreneurs and the expertise they might have to offer.

The same point can be made when a PV dealer purchases products from one of the vertically integrated energy corporations. The dollars spent here are "votes" against a competitive market structure that supports independent entrepreneurs. This is especially true because these "low price" suppliers are also competing with the local installing dealer. These vertically integrated distributors offer their own preassembled "Zero Installation" systems or they market packaged systems through "green" utility programs. Imagine what they will try to do to their "partners" on the down side of the current boom.

PV Experts Discover Y2K

As we all know, the Y2K boom is generating lots of business for dealers, installers, distributors, and manufacturers. It is also stressing the entire product delivery channel while providing a golden opportunity for competent PV companies to grow their businesses. This upsurge in PV business has caught the "experts" totally by surprise. It was with some amusement that I received a request a few days ago for an interview with a researcher from the Stanford Research Institute (a think tank in Palo Alto, California). The researcher had just read a tip in one of those "insider" PV newsletters, and wanted to do a survey on the impact of Y2K on the PV industry. I hope she gets it done before the lights go out!

IPP and our members have not waited on insiders or experts to tell us what to do. We started our companies and installed PV on our rooftops long before common wisdom or market studies said it was a good idea. We were ahead of the "insiders." We have acted out of vision and personal conviction. The "Just Do It!" herald of *Home Power* magazine certainly characterizes the independent PV industry and the people in it. This attitude will continue to be our strength. In uncertain times, entrepreneurial agility, intelligence, conviction, and courage can outperform size and power, especially when we act with our eyes open.

California PV Buydown Program

Reservations for this state-funded rebate program are increasing at a steady rate. As part of utility restructuring, the State of California has set aside 30 million dollars earmarked for rebates to purchasers of PV and small wind systems. The funding is divided into five equal blocks. The funding for Block One, at $3 per watt, is one-third subscribed with about four million dollars remaining. Block Two provides another six million dollars but the rebate drops to $2.50 per watt. Successive six million dollar blocks decrease by $0.50 per watt.

This incentive program supports end users. The program allows a customer to shop for a qualified system in the marketplace. To be qualified, a system needs to meet technical standards only. The rebate is not limited to any specific manufacturers or sweetheart utility deal. Rather, the principal players in the transaction are the customer, a seller, and the California Energy Commission (CEC). The required forms are readily available and the program is being run very smoothly. Sandy Miller at the CEC heads this program.

The California program is unique. By allowing the end user choice, the program supports all elements of the PV industry including the installing infrastructure. The California PV Alliance, headed by Vince Schwent, has done a great job creating this program. The Alliance is also developing a PV and renewables education program that will support the California Emerging Renewables Rebate Program. Though these are California programs, I hope that readers and activists in other states can benefit from our experiences while crafting their own programs.

Five years ago, IPP criticized programs that offered incentives for utility rooftop PV projects. At that time, many in the PV industry thought we were wrong. IPP advocated programs that encouraged individual citizens and businesses to purchase PV. Today we are experiencing growth in the end user market. Though Y2K is providing a kick start, this market will persist. It will persist because customers' needs are supported. What do PV and renewables provide? They provide independence, reliability, backup power, emissions free energy, and even national security.

Next Issue

For *HP72,* we plan to review interconnection issues and distributed generation, and look at what's going on with SEIA and some of the state chapters. Who are the folks at GFI Energy Ventures, the new owners of Trace? I invite readers to contribute information to this column. There is room for many views.

Access

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Code Summary, Checklist, & Manual

John Wiles

Sponsored by the Photovoltaic Systems Assistance Center
Sandia National Laboratories

Photovoltaic (PV) power systems should be installed in accordance with the requirements of the *National Electrical Code® (NEC®).* The local authority having jurisdiction should inspect these systems. The owner should be able to operate the system and know when maintenance is required.

This Code Corner will look at the chapters and articles in the *NEC,* and describe how they apply to PV systems. A checklist is presented that may be used by PV installers and electrical inspectors. Finally, an abbreviated Owner/User Operations and Maintenance manual is presented for use with utility interactive PV systems.

The Code
The *NEC* is divided into nine chapters with numerous articles in each chapter. The first four chapters of the *NEC* are considered general chapters and apply to nearly all systems:

Chapter 1—General

Chapter 2—Wiring and Protection

Chapter 3—Wiring Methods and Materials

Chapter 4—Equipment for General Use

Later chapters in the *NEC* cover specific installations, equipment, and conditions, and serve to modify and expand on the information in the first four chapters:

Chapter 5—Special Occupancies

Chapter 6—Special Equipment

Chapter 7—Special Conditions

Chapter 8—Communications Systems

Chapter 9—Tables

Article 90
Article 90 comes before Chapter 1 in the code. It is important because it describes what the code does and does not apply to. This article also discusses what information is mandatory, permissive, or explanatory.

Chapter 1
Article 100 covers definitions of terms used in the code. These are necessary for understanding the requirements throughout the code. Article 110 establishes general requirements for all electrical installations. Many of the good workmanship requirements are found in this section.

Chapter 2
Article 200 covers grounded conductors and the required color codes for these conductors. Articles 210, 215, 220, 225, and 240 cover circuit requirements and are applicable to both AC and DC circuits. Article 240 covers overcurrent devices and is particularly important to PV systems with multiple power sources and high available short-circuit currents from battery banks. Article 250 contains the grounding requirements and was completely revised in the 1999 *NEC.* Part H in the 1999 *NEC,* starting with Section 250-160, covers the grounding requirements for DC circuits. Article 280 covers the requirements for surge arrestors.

Chapter 3
Article 300 covers wiring methods. This is a meaty chapter of the code and contains most of the wiring methods that are used in PV systems as well as the ampacity tables for conductors (Article 310). Both multiconductor cables and individual cables in various types of raceways are covered in this chapter. The last few articles in this chapter cover the size and conductor limitation requirements associated with outlet boxes, pull boxes, and panel boards.

Chapter 4
In Chapter 4, the most commonly used articles are 400 and 402 on flexible cords and cables, which can be used for PV trackers and some other uses listed in Article 690. Article 430 on motors may have requirements that apply to well pump motors and the like. Article 445 covers the requirements for generators, and Article 450 covers transformers, both of which are used in PV systems. Article 480 establishes the requirements for storage batteries, but some of these are modified by Article 690 when batteries are used in PV systems.

Chapter 5
This chapter covers special occupancies. It generally only applies to PV systems when they are installed on one of these occupancies. Hazardous locations, such as those that might be found on oil rigs, are also covered. The recreational vehicle requirements covered by the code are addressed in this chapter.

Chapter 6
This chapter addresses special equipment, which includes PV systems (Article 690). Other articles that may involve PV power systems include Article 625 on electric vehicles, Article 640 on sound systems, Article 645 on computers, and Article 680 on pools and fountains.

Chapter 7
This chapter deals with special conditions such as emergency systems (Article 700) and standby power systems (Articles 701 and 702). Article 705 covers interconnected power systems that some inspectors look at when inspecting PV systems. The connection between PV systems and other power systems was eliminated in the 1999 code, but is still mentioned in the 1999 *NEC Handbook.* Article 720 addresses systems of less than 50 volts, which applies to many PV systems. However, Article 690 takes precedence when there is a conflict. Some inspectors will apply the requirements for power limited control circuits found in Article 725 to the low-power control circuits in PV systems.

Chapter 9
This chapter contains numerous tables that are used to provide additional information not found elsewhere in the code. For example, Table 8 gives the resistance of cables and that data can be used to calculate voltage drop in PV circuits.

PV Systems Inspector Checklist
It is advisable to get the authority having jurisdiction/electrical inspector involved at the earliest possible stage in the process. That person can provide valuable input to the design and identify potential problem areas before the system is installed. After the renewable energy system has been installed, it may be inspected by the local electrical inspector. Here is an abbreviated checklist that has been developed for use both by electrical inspectors and PV installers. The checklist may be used for early interactions, installation checks, and final inspections. It applies to both stand-alone and utility interactive systems.

The checklist is an outline of the general requirements for PV systems installations, found in the 1996 and 1999 *National Electrical Code (NEC)* Article 690. This list should be used in conjunction with Article 690 and other applicable articles of the *NEC. It* includes inspection requirements for both stand-alone PV systems (with and without batteries) and utility interactive PV systems. Where Article 690 differs from other articles of the *NEC,* Article 690 takes precedence [690-3].

References in brackets [ ] refer to sections in the 1996 NEC *and other relevant documents. Some sections have different numbers in the 1999* NEC. *The 1999* NEC *has been adopted by only a few states. The 1996* NEC *is the most commonly adopted version at this time. Some states are still using the 1990* NEC. *Legislatures and unions take time to change things.*

PV Arrays
- Listed PV modules are available from 6-7 manufacturers [110-3].

Conductors
- 90° C, wet-rated conductors are necessary. If exposed, use conductor type USE-2, UF (not a good choice due to availability and temperature limitations), or SE [690-31(b)]. Use RHW-2, THWN-2, or XHHW-2 in conduit [310-15].
- Conductor insulation must be rated at 90° C [UL-1703] to allow for operation at 70° C or greater near modules and in conduit exposed to sunlight.
- Temperature-derated ampacity calculations should be based on 156% of short-circuit current (Isc), and the derated ampacity must also be greater than the rating of the overcurrent device (156% Isc—see *Overcurrent Protection)* [690-8,9].
- Temperature derating factors of 60-65° C are suggested in cooler areas, 70° C in hotter areas, and 75° C in desert areas for ampacity calculations.
- Portable cords are allowed only on moving tracker connections [690-31(c), 400-3].
- Strain reliefs/cable clamps or conduit should be used on all cables and cords [300-4, 400-10].

Overcurrent Protection
- DC rated and listed fuses and circuit breakers are available from several sources. If the device is not marked DC, then verify the DC listing with the manufacturer.
- Overcurrent protection devices must be rated at 1.56 times short-circuit current (1.25 x 1.25 = 1.56) from modules [UL-1703, 690-8, module instructions]. Both of these 125% factors are now in the 1999 *NEC.*
- Supplementary devices are allowed, but branch-circuit rated devices are preferred [690-9(c)].
- Each module or series string of modules must have an overcurrent device protecting the module [UL-1703/NEC 110-3(b)]. This provision is frequently not used.
- Devices must be located near the charge controller or battery [690-9(a) FPN].
- Devices must protect the smallest conductor used to wire modules. Sources of overcurrent are parallel-connected modules, batteries, and AC backfeed through inverters [690-9(a)].

Charge Controllers
- Listed devices are available separately and inside listed PV power centers [110-3].
- There should be no exposed terminals unless the device is installed in a listed enclosure.

Disconnects
- Listed, DC-rated devices are available: Examples are Square D QO breakers for 12 volt DC systems, and Square D Heavy Duty Fused Safety Switches up to 600 volts DC.
- Listed PV Load Centers by Pulse Energy, Trace, and others for 12, 24, and 48 volt systems contain charge controllers, disconnects, and overcurrent protection for entire DC systems.
- Disconnects must be provided for all current-carrying conductors of PV source [690-13].
- Disconnects must be provided for equipment [690-17].
- Grounded conductors should not be fused or switched, but may have bolted disconnects.
- Connectors may be used as disconnects if they meet 690-33.

Inverters (Stand-Alone Systems)

- Listed stand-alone inverters are available from several manufacturers [110-3].
- DC input currents must be calculated for cable and fuse requirements: Input current equals rated AC output in watts divided by lowest battery voltage divided by inverter efficiency [690-8(b)(4)]. Note: The RMS value of current (particularly with reactive loads) may significantly exceed the average current calculated by this method. RMS current is what heats conductors and fuses.
- Cables to batteries must handle 125% of input currents [690-8(a)].
- Overcurrent devices should be located within 4–5 feet of batteries.
- Overcurrent/Disconnects mounted near batteries and external to PV load centers are suggested if cables are longer than 5-6 feet to batteries or inverter.
- Listed, DC-rated fuses and circuit breakers are available. AIC (amps interrupting current) should be at least 20,000 amps. Littelfuse marks DC rating; Bussmann and others sometimes do not [690-71(c), 110-9]. Verify listed DC rating with manufacturer, if unmarked.
- 120 volt inverters connected to 120/240 volt load centers with multiwire branch circuits have the potential for neutral overloading in the branch circuit [100–Branch Circuit, Multiwire].

Batteries

- None are listed.
- Cables should be building-wire type cables [Chapter 3]. Welding cables and auto battery cables don't meet *NEC* standards. Flexible USE/RHW cables are available. Article 400 cables are OK for cell connections, but not in conduit or through walls [690-74, 400-8]. See *Inverters (Stand-Alone Systems)* for ampacity calculations.
- Access should be limited [690-71(b)]. Install batteries in well-vented areas (garages, basements, outbuildings—not living areas).
- Cables to inverters, DC load centers, and/or charge controllers should be in conduit [300-4].
- Exposed battery terminals should be accessible only to qualified people.

Inverters in Utility Interactive (UI) Systems

- Listed units are available from three manufacturers and should be used for the safety of utility personnel. These units eliminate the possibility of energizing unenergized utility lines.
- UI inverters must be on dedicated branch circuits with backfed overcurrent protection [690-64].
- UI inverters must have external DC and AC disconnects and overcurrent protection [690-15,17].
- Total rating of overcurrent devices connected to an AC load center (main breaker plus PV breaker) must not exceed load center rating (120% of rating in residences) [690-64(b)(2)].

Grounding

- Only one grounding electrode conductor connection (a bonding conductor) to DC circuits (grounded conductor) and one connection to AC circuits (neutral) should be used for system grounding [250-21].
- AC and DC grounding electrode conductors may be connected to the same grounding electrode system (ground rod) [690-41,47, 250-21].
- Equipment grounds are required even on ungrounded, low voltage systems [690-43].
- On 12 volt and some 24 volt ungrounded systems [690-41], disconnects and overcurrent devices are required in both of the ungrounded conductors in each circuit [240-20(a)].
- Equipment grounding conductors for DC circuits from PV arrays may be run apart from other conductors [250-57 (b) Ex 2]. This routing is suggested to minimize damage in areas where lightning surges are common.

Conductors (General)

- Standard building-wire cables and wiring methods can be used [300-1(a)].
- Wet-rated conductors should be used in conduits in exposed locations [100 Definition of Location, Wet].
- DC color codes are the same as AC color codes—grounded conductors are white and equipment grounding conductors are green or bare [200-6(a), Ex 5]. Ungrounded terminals/conductors should be labeled to show polarity.

Owner/User Operations and Maintenance Instructions For Utility Interactive Photovoltaic Power Systems

After the system has been installed and inspected to ensure that it meets the safety requirements of the *NEC,* the installer/vendor should work with the owner/user to ascertain that the owner knows how the system is supposed to operate. While maintenance is not normally done by the owner, that person must at least know when the system is not performing properly so that service personnel can be notified. The brief manual presented below is intended for the owner of a utility interactive PV system.

Introduction

utility interactive photovoltaic (PV) electrical power systems in general require relatively little user operational involvement/control and low levels of user maintenance. These systems tend to operate well until there is some sort of component failure and then a qualified person such as an electrician or electrical contractor must usually perform maintenance actions.

In no case should the unqualified owner/user open any cabinet, enclosure, or junction box containing electrical wiring. These systems are electrical power systems, and as such may pose hazards when an untrained, unqualified person attempts to troubleshoot or repair them.

System Performance Verification

After the system has been installed and has been inspected

for safety by the authority having jurisdiction (electrical inspector), the installer/vendor should turn on the system and demonstrate the proper operation to the user/owner. The installer should test the system on a bright, clear, sunny day using a pyranometer (to measure the solar resource) and AC wattmeter (to measure the AC power out of the system) and document the system performance.

Operation

In nearly all cases, utility interactive systems will automatically start to produce power whenever the sun is shining, the utility grid is present, and all disconnects are closed. There are no controls that need to be operated or adjusted on a daily or other periodic basis. The installer/vendor should close all disconnects at the time of installation and show the owner/user where they are located. In many cases, these disconnects will also be circuit breakers that can trip open under fault conditions. If there are user serviceable fuses, the installer should also show the owner/user where they are located and how to change them. These basic instructions should be documented and presented to the owner/user at the time of installation.

Each system indicates power production in a different way. Some inverters may have numerical or meter power displays, some may have flashing lights, and others may have only a kilowatt-hour meter on the output. A few systems may have no readily discernible method of determining if the system is operating. Depending on the utility billing and the way in which the energy is measured, there may or may not be an indication in the utility bill of the amount of energy that is produced from the PV system.

The installer/vendor should show the owner how the PV output can be observed (digital readout, flashing light, KWH meter dial spinning, etc.). On subsequent sunny days, the user may make the same observation to determine qualitatively that the system is operating. If the energy production is metered (kilowatt-hour meter) or appears on the utility bill, then the customer may estimate performance from month to month based on this reading and the estimated number of sunny days.

Some newspapers report a solar index related to the amount of solar energy each day and this may be correlated with an energy meter reading for more of a quantitative evaluation of system performance. It should be noted that shading and microclimate at the site of the PV system may result in significantly different levels (usually lower) of available solar energy than the numbers from an official solar monitoring station. If the qualitative or quantitative assessment indicates that the PV system is not performing as expected, maintenance actions should be initiated.

Maintenance

When maintenance actions are indicated, the owner/user should verify that all disconnects/circuit breakers are closed, as they were at the time of the initial installation. User serviceable fuses that are thought to be open (blown) may be changed for fuses that are known to be good. Instructions provided by the system installer should show how to do this.

If circuit breakers continue to trip open, fuses continue to blow, or the qualitative/quantitative indicators of correct performance do not become normal, then the owner/user should contact the installer/vendor or other qualified person. This qualified person should troubleshoot the system, find and correct any deficiencies, and then retest the system for power output while measuring the solar resource.

Periodically (once every year or two), the owner/user should have the AC output of the system tested by a qualified person while the solar resource is measured to determine if the system meets the expected or warranted performance levels.

Summary

Happy owners and profitable PV installations are ensured by using listed equipment, installing to code, inspecting for safety, verifying performance, and ensuring that the owner understands how to operate the system and monitor the performance.

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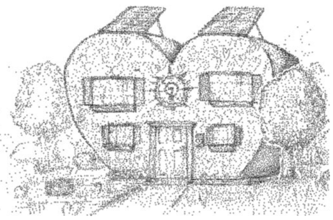


Kathleen Jarschke-Schultze

I get a lot from my readers. I am sure *Home & Heart* is being read, since I receive feedback regularly. This is a good thing. I don't know everything (don't tell Bob-O). I believe I am practical, and that accounts for a lot. Having people send me information and corrections from around the globe is swell. I really appreciate it.

Bleach Plus Water

In *HP69* I mentioned using chlorine bleach to purify water. I did not mention specific amounts or instructions. I would expect that anyone trying this would research the method first. I received the following note:

Please, next time you should specify that it must be plain bleach, not "scented" or "perfumed." These additives cause stomach distress, in other words, diarrhea. If you don't believe this, make a pot of tea with "Lemon Fresh" or "Fresh Mint" bleach added to your water. Caution: stay close to the bathroom. Some people may have stored water with the incorrect bleach!

Yikes! If you've stored water using the wrong bleach, throw it out and start fresh. The American Red Cross has excellent instructions and disaster preparedness lists available. I was so clueless I didn't even know there *were* scented bleaches. I only get the plain old kind and it lasts a long time since I don't use it for laundry.

East and West

In *HP65 & 66* I gave some instructions on solar cookers. I said that focusing "is done by standing behind your cooker and pointing it so that there is a slight shadow on the *left* hand side of the cooking area. This way the sun will always be coming into focus, keeping the food at maximum temperature, rather than unfocusing and lowering the temperature."

A. J. Oxton sent me this via e-mail:

When you talk about which way to orient a solar cooker using terms like "left" and "right," keep in mind that the "handedness" of the sun is reversed in the southern hemisphere. Think about it. When you folks in California look at the sun, it moves from left to right; but if you were to set up your solar cooker in New Zealand where the sun moves from right to left, your instructions would produce undesirable results. Saying east and west instead of right and left would relieve that ambiguity.

Thanks, A.J. I never consciously realized that. I knew that water spiraled down drains opposite of ours in the southern hemisphere, but my brain took it no further. So, here is my final word on the subject of focusing solar cookers:

Focusing is done by standing behind your cooker and pointing it so that there is a slight shadow on the *west* side of the interior cooking area. This way the sun will always be coming into focus, keeping the food at maximum temperature, rather than unfocusing and lowering the temperature.

Solar Cookbook

Jennifer Stein Barker has done it again. First she published an excellent whole foods cookbook, *The Morning Hill Cookbook.* I always recommend this book in my solar cooking workshops. She has many solar recipes in the book. They are designated with a little sun by the recipe title. All are great.

Now she has published *The Morning Hill Solar Cookery Book.* I am excited. As I've said before, Jennifer knows how to cook. This is a whole foods cookbook and totally vegetarian. However, as she states in the beginning of the book, meat can be added to any dish. Bob-O and I are omnivores and eat meat three to four times a week, but who could resist Tamale Pie or Pesto Roly-Poly.

One aspect of the book I really like is that each recipe comes with instructions for conventional cooking. Jennifer says this is because you might want to eat a certain dish on a rainy day. How practical—I love that.

There is a whole section on yeast breads. This is a food that can give new solar cooks problems. Jennifer has wonderful, exciting recipes and full technique explanations. From Pain Rustique to Onion Herb Rolls, it's covered here. With a solar cooker and this book, you will be ready for the coming summer with easy, efficient, fuel-free food.

This book is entirely a community-made project. By utilizing local talent and businesses, Jennifer is able to keep all the book proceeds in her small county (pop. 8,000). Jennifer is also a renewable energy activist.

She's organizing SolWest, a major RE fair for the western U.S. Join the *Home Power* crew there on July 24 and 25.

Bee Good

I have started a new adventure—keeping bees. Bob-O kept bees before I knew him, but I have never had the experience. I have been reading voraciously on the subject. My favorite book is *The Art and Adventure of Bee Keeping,* by Ormand and Harry Aebi, published by Rodale Press in 1975. It is very inspiring and easy to read. Unfortunately, it is now out of print, so you'll have to look for it in used bookstores.

I ordered hives and supers. These come unassembled, so I have been gluing and hammering a lot on the dining room table. My bee equipment now covers any level space. It is very cool. There is a whole uniform, complete with hat and veil. Betty Davis has nothing on me for style.

There has been a dearth of wild bees, not only in our area but nationwide. Last year when our apple and peach trees were blooming, there were hardly any honey bees on them. Back when Bob-O had bees, he captured swarms. I will be using packaged bees. By the time this goes to print, I will have driven two and a half hours south to a bee ranch and picked up my bees.

I am excited and somewhat apprehensive. Bob-O will be gone that weekend to help teach a solar workshop in Arcata, on the coast. By the time he gets back, the bees will be in their new homes, feeding on sugar syrup so they can get some brood going. At least that is the scenario I am aiming for.

Apparently, when you have hives close together, it is a good idea to paint one a different color. That way, it is easier for the bees to identify their particular hive. I think a large colorful design would work, so I am thinking of a large, dark blue Celtic knot on the front of one. This is going to bee fun.

Access

Kathleen Jarschke-Schultze is preparing for her friends, the bees, at her home in Northernmost California, c/o *Home Power* magazine, PO Box 520, Ashland, OR 97520 • 530-475-0830
kathleen.jarschke-schultze@homepower.com

The Morning Hill Solar Cookery Book, US$14.95 postpaid and *The Morning Hill Cookbook,* US$13.95 postpaid from Jennifer Stein Barker, Morning Hill Associates, HC 84 Box 632, Canyon City, OR 97820
541-542-2525 • solwest@eoni.com
Make check payable to Jennifer Stein Barker.
Write for volume pricing for co-ops, groups, and stores.

BACKHOME MAGAZINE

b&w on film

3 wide
5.8 high

sames as HP70

HAPPENINGS

INTERNATIONAL

Summer/semester internships in appropriate tech projects (cookstoves, windpumps, ag extension and outreach technologies). EnterpriseWorks, a US-based NGO (formerly Appropriate Technology International), has offices in Africa, India, Sri Lanka, and Mexico. Candidates evaluated on technical and economic background and language skills. Info: Ed Perry, Perrye@enterpriseworks.org

CANADA

EarthFEST'99, Aug. 14-15, Courtenay, BC. Fun, exhibits, and workshops emphasizing food, energy, shelter, transportation, water, waste, and sustainable communities. Non-profit volunteer event sponsored by Solar Energy Society of Canada and Canadian Organic Growers. Info: EarthFEST'99 Site Office, 2050 Pine Place, Courtenay, BC, Canada V9N 3C1 • 250-334-8694
Fax: 250-334-8695 • earthfest@web.net
www.web.net/earthfest

Aug. 11-14, North Sun '99. Biennial Conference on Solar Energy in high latitudes. Edmonton, Alberta. Info: Solar Energy Society of Canada, 116 Lesgar St. #702, Ottawa, Ontario K2P 0C2, Canada +1-613-234-4151 • Fax: +1-613-234-2988
northsun.99@cyberus.ca
www.solarenergysociety.ca

Alberta Sustainable House: Open on 3rd & 4th Saturdays (except holiday weekends), 1-4 PM, free. Cold-climate features/products based on health, environment, conservation, AE, recycling, low energy, self-sufficiency, & appropriate technology. Contact: Autonomous & Sustainable Housing, 9211 Scurfield Dr NW, Calgary, Alberta T3L 1V9, Canada • 403-239-1882 • Fax: 403-547-2671
jdo@acs.ucalgary.ca
www.ucalgary.ca/~jdo/ecotecture.htm

Electric Vehicle Society of Canada, Toronto Chapter promotes EVs (and has fun!). Enthusiasts, inventors, Sunday mechanics & environmentalists. Meetings: 3rd Thursday each month, Sept-June. New members welcome! Info: Howard Hutt, 21 Barritt Rd, Scarborough, Ontario, M1R 3S5, Canada
416-755-4324

The Institute for Bioregional Studies demonstrates & teaches ecologically-oriented, scientific, social & technological achievements for ecological, healthy, interdependent & self-reliant communities. Info: IBS, 449 University Ave, Charlottetown, Prince Edward Island C1A 8K3, Canada
902-892-9578

Vancouver Electric Vehicle Association, Call for meetings. Info: 1402 Charlotte Rd., North Vancouver, BC V7J 1H2, Canada
604-987-6188 • Fax: 604-253-0644
rcameron@statpower.com

COLUMBIA

Oct 11, '99: Expouniversidad 99—Energia, desarrollo y calidad de vida. Mechanical Engineering University of Antioquia, Medellin. Info: Marina Carvajal, carvaja@udea.edu.co

PORTUGAL

Nov 10–14, '99: International Exhibition on Environmental Technology, Energy & Natural Gas. Info: Feir Internaciojnal De Lisboa
351-1-360-1500 • Fax 351-1-363-3893
expoambiente@aip.pt • www.emml.com

NATIONAL U.S.

American Hydrogen Association nat'l headquarters: 1739 W. 7th Ave, Mesa, AZ 85202-1906 • 602-827-7915 • Fax: 602-967-6601 • aha@getnet.com • www.clean-air.org

American Wind Energy Association. Info about U.S. wind energy industry, AWEA membership, small turbine use, & more.
www.igc.org/awea

National Summary Reports on State Financial and Regulatory Incentives for RE. To order: North Carolina Solar Center, Box 7401 NCSU, Raleigh, NC 27695
919-515-3480 • Fax: 919-515-5778
www.ncsc.ncsu.edu/dsire.htm

Energy Efficiency and Renewable Energy Clearinghouse (EREC) offers free info: Insulation Basics (FS142), New Earth-Sheltered Houses (FS120), PV: Basic Design Principles & Components (FS231), Cooling Your Home Naturally (FS186), Automatic & Programmable Thermostats (FS215), & Small Wind Energy Systems for the Homeowner (FS135). Info: EREC, PO Box 3048, Merrifield, VA 22116 • 800-363-3732
TTY: 800-273-2957 • energyinfo@delphi.com
www.eren.doe.gov

Oct 16: National Tour of Solar Homes. Info: ASES, 2400 Central Ave #G-1, Boulder, CO 80301 • 303-443-3130 • ases@ases.org
www.ases.org/solar

Energy Efficiency and Renewable Energy Network (EREN) provides links to hundreds of gov't and private internet sites & offers an "Ask an Energy Expert" online questions to specialists. www.eren.doe.gov
800-363-3732

Green Power web site: Forum discussing green power including deregulation, "green" electricity choices, technology, marketing, standards, environmental claims, & varying national & state policies. Links, articles & news. Global Environmental Options (GEO), & the Center for Renewable Energy & Sustainable Technology (CREST).
www.green-power.com

Kids to the Country, an ongoing program to show at-risk urban children a country alternative. Info: PLENTY, 51 The Farm, Summertown, TN 38483 • 615-964-4391
ktc@thefarm.org

Tesla Engine Builders Association (TEBA): info & networking. One version is reported to consume 38 lbs of steam per HP/hr. Send SASE to TEBA, 5464 N Port Washington Rd Suite 293, Milwaukee, WI 53217
teba@execpc.com • www.execpc.com/~teba

Sandia's web site includes "Stand-Alone Photovoltaic Systems: A Handbook of Recommended Design Practices," "Working Safely with PV," & balance-of-system technical briefs, providing information on battery & inverter testing
www.sandia.gov/pv

Solar Energy & Systems, Internet college course. Fundamentals of small RE. Weekly assignments reviewing texts, videos, WWW pages, weekly chat room, & email Q&A. Mojave Community College. $100 plus $10 registration. 800-678-3992
lizcaw@et.mohave.cc.az.us
chacol@hal.mccnic.mohave.az.us

Federal Trade Commission, free pamphlets: Buying An Energy-Smart Appliance, EnergyGuide to Major Home Appliances, & EnergyGuide to Home Heating and Cooling. Contact: EnergyGuide, FTC, Rm. 130, 6th St & Pennsylvania Ave NW, Washington, DC 20580 • 202-326-2222 • TTY: 202-9326-2502
www.ftc.gov

The Interstate Renewable Energy Council, SEIA, & Sandia: handbook for state and local government procurement officials and others in the specs and purchase of RE. US$15 ppd (make checks to ASES), Interstate RE Council Distr. Center, c/o ASES, 2400 Central Ave Ste G-1, Boulder, CO 80301

Solar curriculum for upper elementary & intermediate grades—Free! Six week science curriculum or individual sessions creating awareness of solar energy and demonstrating basic solar. Over 30 classroom presentations and demos using free or low cost materials. Student tested, teacher approved. Florida Solar Energy Center, Susan Schleith • 407-638-1017
www.fsec.ucf.edu

ALABAMA

The Self-Reliance Institute of NE Alabama seeks others interested in RE, earth sheltered construction, & other self-reliant topics. Info: SINA, 6585 Co. Rd 22, Centre, AL 35960 • cevans9@tds.com

ARIZONA

Tax credits for solar in Arizona. A technician certified by the AZ Department of Commerce must be on the job site. Info: ARI SEIA, 602-258-3422

CALIFORNIA

Campus Center for Appropriate Technology,

Humboldt State University, Arcata, CA. Ongoing workshops and presentations on a variety of alternative, renewable, and sustainable living subjects. Contact: CCAT, HSU, Arcata, CA 95521 • 707-826-3551 ccat@axe.humboldt.edu www.humboldt.edu/~ccat

Cob Building Workshops. Nevada City. June 15-21, Oct 13-19. Info: Madeleine Curtis-Mead, 11145 Tyler Foote Rd, Nevada City, CA 95959 • 530-292-3562

Home Education Conference, Radisson Hotel in Sacramento Aug 20-22. Non-religious home-schooling conf. Info: Barbara David, PO Box 231324, Sacramento, CA 95823 • 916-391-4942 • CHEC95@aol.com www.HomeEdConference.com

Rising Sun Energy Center. Ongoing solar energy classes incl. electricity, water heating, cooking, & kids day. Schedule and info: PO Box 2874, Santa Cruz, CA 95063 408-423-8749 • sunrise@cruzio.com www.cruzio.com/~solar

Siemens Solar offers PV training: Basic PV Technology Self-Study Course, & Comprehensive Photovoltaic System Design Seminar. Contact: Siemens Solar Training Dept, 805-388-6568 • Fax: 805-388-6395 cvernon@solarpv.com • www.solarpv.com

June 26–27, '99: 4th annual SolFest, Solar Living Center, Hopland, CA. Speakers, educational workshops on renewable energy and sustainable living, entertainment, renewable energy booths, electric car parade, & more. 707-744-2017 www.realgoods.com

Institute for Solar Living, Sustainable Living Workshop series through October '99. Beginning & advanced solar electric systems, passive solar, ecological design, sustainable waste water design, straw bale, cob & rammed earth construction, & more. 800-762-7325, or write ISL, PO Box 836, Hopland, CA 95449

NCSEA Sacramento Solar Speaker Series, SMUD Customer Service Center, second Monday of every month, 7 to 9 PM. Speaker info, call 916-44-SOLAR

COLORADO

Crestone Energy Fair, Sept 5-6, Crestone, CO. Dealers, vendors, musicians, and builders together for sunny fun in the park. Solar and alternative building. Tour homes using PV, wind, solar thermal, straw bale, earthships, adobe, and more. Info: 719-256-4838

Solar Energy International, hands-on workshops: solar, wind, & water power. One & two week sessions: PV Design & Installation, Advanced PV, Wind Power, Micro-hydro, Solar Cooking, Environmental Building Technologies, Solar Home Design, & Straw Bale Construction. Experienced instructors & industry reps. For owner-builders, industry technicians, business owners, career seekers, & international development workers. $500/week. SEI, PO Box 715, Carbondale, CO 81623 970-963-8855 • Fax: 970-963-8866 sei@solarenergy.org • www.solarenergy.org

National Wind Technology Center, Golden, CO. Assisting wind turbine designers & manufacturers with development & fine tuning. Computer modeling & test pads. Call in advance: 303-384-6900 Fax: 303-384-6901

FLORIDA

August 23–25, '99: 2nd Annual Energy '99, Achieving Your Goals Conference, Orlando, Florida. For energy professionals interested in energy & water efficiency, & renewable energy. Contact: JoAnn Stirling 800-395-8574 • Fax 407-638-1010 joann@fsec.ucf.edu www.energy99.ee.doe.gov

GEORGIA

NAEVI '99, N. American EV & Infrastructure Conference, Nov 17-20, Atlanta, GA. Info: EVAA, 601 California St. #502, San Francisco, CA 94108 • 415-249-2960 Fax: 415-249-2699 • ev@evaa.org www.evaa.org

IDAHO

Sunplugged Fair, July 3-5, Sandpoint. PV-powered music and street dancing, PV and related exhibits, building materials exhibits, home-built electric vehicles, crafts & food booths. 90 minutes NE of Spokane. City parade, fireworks, lake and swimming beach, boating, and mt. country are added attractions. Info: Sunplugged 206 N 4th Ave #101, Sandpoint, ID 83864 • 208-265-7070 Fax: 208-265-6788 sunplugged@sandpoint.net

IOWA

Sept 23–26, 1999: IRENEW Energy Expo/Convention. Sheraton Hotel and Convention Center, Cedar Rapids, Iowa. Events, solar cars, electric cars, Cedar Rapids electric bus, Electrathon, demos. Workshops: PV, wind, active vs passive, political issues. Iowa Electrathon Race. Info: I-Renew, PO Box 466, North Liberty, Iowa 52317 • 319-338-3200 • irenew@irenew.org www.irenew.org

Iowa Renewable Energy Association (IREA) meetings: 2nd Sat every month at 9 AM, Prariewoods, Cedar Rapids. All welcome. Call for schedule change. I-Renew, PO Box 466, North Liberty, Iowa 52317 319-338-3200 • irenew@irenew.org www.irenew.org

KENTUCKY

Appalachia-Science in the Public Interest. Projects & demos in gardening, solar, sustainable forestry, & more. Info: ASPI, 50 Lair St., Mt. Vernon, KY 40456 606-256-0077 • aspi@kih.net www.kih.net/aspi

MAINE

June 12-17, Solar '99: Growing the Market, American Solar Energy Society's Annual Conference. Taking solar into the 21st century. Growing strong & sustainable markets. Portland, ME. Info: NESEA, 413-774-6051 • Or: ASES, 303-443-3130 ases@ases.org • www.ases.org/solar

June 7—12, Women's PV Design & Installation Workshop, Portland. Hands-on basics of electricity, site analysis, system components, wiring & safety. Women instructors from the RE field. In conjunction with the ASES conference, Solar '99. Contact SEI, PO Box 715, Carbondale, CO 81623 970-963-8855 • Fax: 970-963-8866 sei@solarenergy.org • www.solarenergy.org

Maine Solar Blast & Back Cove Family Days, June 12-13, Payson Park, Portland ME. Solar-powered music, exhibits, demos, electrathon, jr. solar sprint, food, and workshops. Energy fair on 12th, community celebration on 13th. Free. Info: City of Portland Parks & Rec, 17 Arbor St, Portland, ME 04103 • 207-874-8739 tvm@ci.portland.me.us

MARYLAND

1999 Summer Sun Energy Fair, June 5, Montgomery College, Germantown, MD. Exhibitors, displays, workshops, & entertainment. Sponsored by Potomac Region Solar Energy Association and Montgomery College. • www.prsea.org

MASSACHUSETTS

Greenfield Energy Park needs help preserving Greenfield's historic past, using today's energy & ideas, creating a sustainable future. Info: Greenfield Energy Park, NESEA, 50 Miles St, Greenfield, MA 01301 • 413-774-6051 • Fax: 413-774-6053

Sustainability Series, workshops and lectures, Sept-Dec 99. Info: NESEA, 50 Miles St, Greenfield, MA 01301 • 413-774-6051 Fax: 413-774-6053 • nhazard@nesea.org www.nesea.org

MICHIGAN

Tillers International, classes in draft animal power, small farming, blacksmithing, & woodworking. Catalog: Tillers Int'l, 5239 S. 24th St., Kalamazoo, MI 49002 616-344-3233 • Fax: 616-344-3238 TillersInt@aol.com • www.wmich.edu/tillers

MONTANA

Sage Mountain Center: Life Skills Workshops. One day classes: Inexpensive earth-friendly home building, straw bale construction, log furniture, cordwood construction, natural & non-toxic interiors, & more. $55 incl literature. Info: SMC, 79 Sage Mountain Trail, Whitehall, MT • 406-494-9875

NEW MEXICO

Profit From The Sun workshop series, Moriarty, NM. Renewable energy, energy conservation, sustainable living, & energy independence. Contact: James or Marek at

PSF,Inc, 505-832-1556 days; or James at 505-832-1575 eves & weekends proffit@flash.net

NORTH CAROLINA

How to get Your Solar Powered Home, RE seminars through summer of 2000. Info: Solar Village Institute, PO Box 14, Saxapahaw, NC 27340 • 336-376-9530 solarvil@netpath.net

OHIO

Solar/wind classes at rural solar & wind powered home. Second Saturday of each month, 10 AM to 2 PM. Tech info, system design, NEC compliance, efficient appliances. See equipment in use. Max 10 students. Register in advance. $65/person $85/couple (spouse only). In spring: hands-on straw bale post & beam building. Solar Creations, 2189 SR 511 S., Perrysville, OH 44864 • 419-368-4252 www.bright.net/~solarcre

OREGON

Permaculture Design Course, June 14-25, Williams. Design course by Tom Ward and Jude Hobbs, $850. Info: Panther Gulch Permaculture, 963 Panther Gulch Rd, Williams, OR 97544 • 541-846-6407

Cob Building Workshops: June 28-July 4, Talent, OR. Info: Lois Lewis, 233 Eva Way #35, Talent, OR 97540 • 541-535-3878

Aprovecho Research Center, non-profit educational institute on forty acres in the OR forest. Internship Sept 1. Also, six week winter internship in Baja, Mexico: Study and research appropriate tech applications, learn Spanish, teach grade school, & work fruit orchards & gardens. Info: Internship Coordinator, Aprovecho Research Center, 80574 Hazelton Rd., Cottage Grove, OR 97424 • 541-942-8198

Solar Energy Association of Oregon: 20th Anniversary Conference, Oct 2, '99, World Trade Center, Portland. All day event. Keynote speakers Jeff Cook, Regents Professor, Passive Solar Architect & Educator from Arizona State University, & John Reynolds, Univ. of Oregon, Building Energy Specialist. Speakers including Curtis Framel from the USDOE Million Solar Roof Program & Larry Sherwood from the Am. Solar Energy Society. Trade Show (open to the public), Building Projects & workshops, local solar energy specialists. Contact SEAO: 503-231-5662 • 205 SE Grand Ave, suite 202, Portland, Oregon 97214 www.oikos.com/seao

July 16-21, '99: Strawbale workshop—Gonzo Survival Structure; Mosier, Oregon. 5 day workshop constructing an earthsheltered strawbale structure. Sponsored by solar7.83 design studio and Portland Community College. $300 per person. Mandatory meeting July 14, 7-9pm (see PCC summer catalog for more info, www.pcc.edu). More workshop info is available at www.solar783.com or by contacting Candace Gossen at cgossen@solar783.com 503-236-0915 • Fax: 238-6607

TENNESSEE

July 24, '99: One day intensive solar workshop: The Farm in Summertown. Install a cabin system. $75, veggie lunch included. Info: 931-964-4927 • fecc18@hotmail.com

TEXAS

The El Paso Solar Energy Association offers a bilingual web page. Info in Spanish on energy and energy saving. www.epsea.org www.epsea.org

WASHINGTON

GreenFire Institute: workshops and info on straw bale construction. GreenFire, 1509 Queen Anne Ave #606, Seattle, WA 98109 206-284-7470 • Fax: 206-284-2816 wilbur@balewolf.com • www.balewolf.com

1999 Hands-On Permaculture Workshops. Sustainable ecological design at a premier permaculture site—The Bullock Brothers' Homestead, Orcas Island, WA. Permaculture Skills Intensive, July 10-August 6; Water Harvesting, September 17–20. Contact: Bullock Workshops, c/o WE-Design, PO Box 45472, Seattle, WA 98145 or Michael Lockman, 206-567-5447 michaellockman@juno.com

WISCONSIN

June 18-20, '99: 10th Annual Midwest Renewable Energy Fair, Amherst, Wisconsin. Hundreds of workshops, speakers, exhibits, and demonstrations. Events for children, educators, and the public. Bus and bike tours of RE homes, on-site model home, & entertainment. Info: MREA, PO Box 249, Amherst, WI 54406 • 715-824-5166 Fax: 715-824-5399 • mreainfo@wi-net.com

Midwest Renewable Energy Association (MREA) Workshops. See ad in this issue. Call for cost, locations, instructors & further workshop descriptions. MREA Membership & participation: all are welcome. Significant others 1/2 price. Info: MREA, PO Box 249, Amherst, WI 54406 • 715-824-5166 Fax: 715-824-5399 • mreainfo@wi-net.com

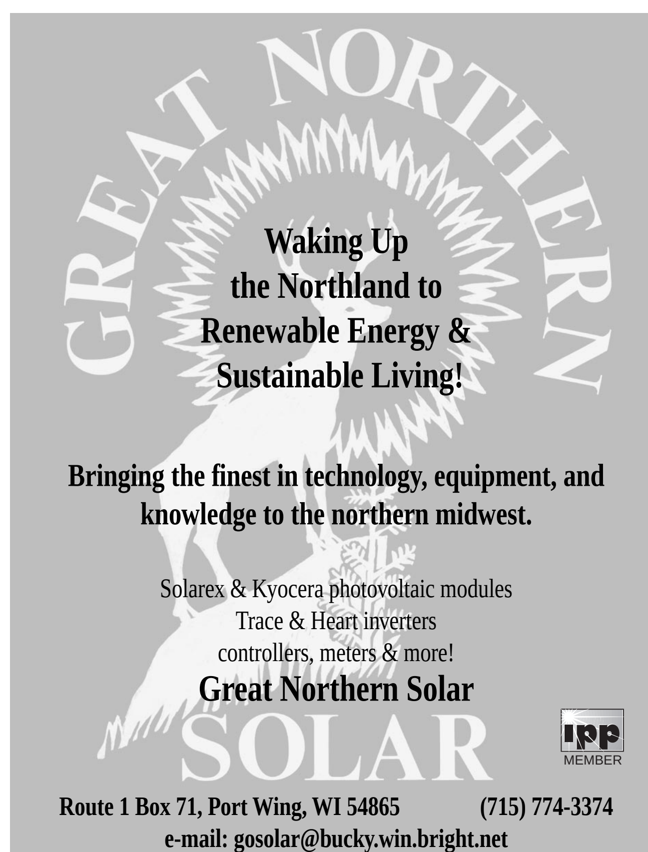
the Wizard speaks…

Where Are They?

For many years now it has been suggested that devices could be built which would tap the quantum energy inherent in the vacuum of space. Many experiments have shown that there is energy there to be harvested. However, there are still no energy generators of this type on the market today. Why not?

It appears that the answer could be quite simple. It may be that this type of energy generator is highly dependent on local conditions. These conditions include gravitational and electromagnetic fields as well as the local structure of space itself. Such conditions could themselves be affected by materials and fields associated with the device and its operation. These devices may also be affected by climatic and solar factors. There have been some experiments which seem to indicate variations which are dependent on place, time of day, and time of year.

Under some conditions, free energy is generated. Under others, it is not. Devices built and tuned to work in a certain overall local environment often fail when that environment is changed. Until this apparent dependence on local conditions is overcome, commercialization of these processes may not be feasible.



Veggie Truck
Dear *Home Power,* In southern Maryland, the Veggie Van article in *HP65* has prompted a spin-off. John Wiles, III (son of *HP Code Corner* author John Wiles) has converted a Volkswagen Diesel Rabbit Pickup to run on recycled vegetable oil. John is the Maintenance Manager for four McDonald's restaurants and has modified a surplus deep fryer to produce the biodiesel fuel from used cooking oil. Needless to say, the paint job and the odor from the exhaust always draw a crowd when he is stopped. John Wiles, Las Cruces, New Mexico

Guerrillas and Utility Workers
Hi! Love your Web site. Read the article on guerrilla solar with great interest. I am presently building an off-grid home and researching solar alternatives.

I also work for the local utility company. As such a worker I have concerns about folks hooking their solar array into the grid without a disconnect. If these folks are sure they won't backfeed the power system and kill me while I'm working on a powerline, then great. If their reason for taking a chance is to save a few bucks and act like nonconformists, shaking their bravado in the face of faceless corporations just for the sake of feeling brave and daring, then I don't appreciate them being so callous with my life. I'm sure my family feels the same way.

What's the big deal with backfeeding the grid anyway? What do they get out of it? Would love to know. Sincerely, A. Denny Wallace • denman@amigo.net

Hello A. Denny, read the article by Joe Schwartz in this issue, starting on page 58. Joe clarifies the technical parameters of utility intertie inverters. There are no technical differences between an authorized utility intertied system and a guerrilla system. The only difference is utility authorization. A guerrilla solar electric system is basically a net metering system, but without all the red tape and hassle.

In an ideal world, the utilities would be clamoring for more green energy to be placed on the grid, and approval would be fast, easy, and painless. It gives me hope to know that four more states have recently adopted net metering laws. This means that in over half of the states in the USA, utilities are required to accept our green energy on their grid. Thanks to all the folks out there who are supporting this goal! Joy Anderson

50 to 200 mA = Ventricular Fibrillation
Dear *Home Power,* I am a lineman for a southern Illinois co-op. I am also interested in renewable energy, just like you guys. I became very disturbed reading your article on guerrilla solar.

Some of the things your authors said were, "We felt that the worst case scenario would be the utility shutting off our power until we de-installed the illegal PV system" (I think the worst case scenario would be to kill someone who is trying to restore your power); "Safety isn't the issue" (I think safety is the main issue); "The supposed problem is that a PV system feeding power to the grid could keep doing so when the grid goes down" (it isn't a supposed problem, it is a real problem); "This would put the line workers in jeopardy of being shocked when they are not expecting live power lines" (not just shocked, how about in jeopardy of being electrocuted?).

What's the big deal? You say a 24 volt solar cell isn't going to shock anyone, much less electrocute them. The problem is the transformer that feeds your house. It normally steps the voltage down from about 7,200 to 120/240. What happens when the 7,200 line is dead and the 120/240 side is feeding the transformer? It now becomes a deadly step-up transformer! The transformer I just mentioned has a 60-1 turns ratio; 7200 / 60 = 120. Whatever voltage is fed into the secondary side would be multiplied by 60 when it is acting as a step-up transformer. 24 volts X 60 = 1,440 V. The solar panel they used was a small one, 108 W at 24 V. Using Ohm's law, 108 W / 24 V = 4.5 A. In our step-up transformer example, the voltage would be multiplied by 60 and the amperage would be divided by 60: 4.5 A / 60 = 0.075 A.

Can 1,440 V at .075 A kill someone? You bet it can! 0.075 A = 75 milliamps. 0.5 to 2 mA = threshold of perception; 2 to 10 mA = muscular contraction (mild to strong); 5 to 25 mA = painful shock, inability to let go; over 25 mA = violent muscular contraction; 50 to 200 mA = ventricular fibrillation occurs.

This is a real concern. What if it were a larger solar panel? What if there were two forms of alternate energy trying to feed the grid? Alternative energy is a good thing, but it needs to be disconnected from the grid when the grid goes down. Pass this on for my safety please. Mike Ellis mechanicmi@aol.com

Mike, I certainly agree with your analysis concerning step-up ratios and the potential lethal voltages that could occur if an operating inverter remained connected to a cold line. One point that is being missed is that the inverters have

automatic disconnects that remove the grid from the inverter input if for any reason the grid goes out. In fact, the inverter will disconnect for a number of reasons including high or low voltage, and high or low frequency. All grid-connected inverters have these features (IEEE P929) in addition to NEC and UL requirements for the same. In addition, all inverters will be provided with manual disconnect means (NEC 690). It can't get much safer than this. I want you to know that no one is advocating unsafe interconnection practices or installing unsafe inverters. In each case of guerrilla solar, this point is made, but I guess not plainly enough.

We installers and business people associated with renewables generally have a high regard for the line personnel. You guys are in the trenches, so to speak, as many of us installers feel we are.

We do, however, take offense at the bureaucratic legal and administrative policies of most utilities and the obstructionistic behaviors they exhibit with respect to the widespread implementation of user-owned independent power. It's a control issue, not a safety issue. Don Loweburg, Independent Power Providers

Putting 14,000 Watts on the Grid
Dear *Home Power,* I read your article on guerrilla solar. As an electrical engineer, I agree that most of the regulations are cumbersome and ridiculous. But I have a couple of questions. Does the inverter automatically match the phase of the grid? Do you have any information on how much power you can send back into the grid before the power company has a problem? I know ideally this should be limited by the wire size and inverter.

The reason I ask is that I have been doing hydroponics seriously for the last year. I want to make it totally self-powered. But I would also like to have the option of expanding the system to lower my power bills. My goal is to put solar panels over my deck to provide shade and power.

One final comment: I have been using "smart" light switches and outlets in my house for over a year. These are controlled by the computer network in my house. It runs everything: heat, lights, fish tanks, hydroponics, air conditioning, etc. I figure that it saves me between 15-30% (depending on the season) on my power bill just by monitoring and regulating the house systems. It significantly lowers power usage when I am not home. If you have any tricks I am not aware of I would appreciate the information. Your readers might be interested as well. Thanks in advance, Brian Eppich • beppich@hotmail.com

Hello Brian. Home Power *has printed five guerrilla solar articles so far, including the two in this issue. The first one answers many of your questions (you can get it at www.homepower.com/rogues.htm). Yes, the inverters we are talking about use the grid's AC signal to synchronize, hence the term "synchronous inverter." They do this automatically, and when they lose the signal from the grid, they stop putting power on the grid.*

The amount of power you can put onto the grid at any one time is limited only by the equipment you have that connects you to the grid. As long as your cabling and service box will handle it, there should be no problem with the utility absorbing it. If your system is huge, then at some point the utility may wonder why your bill has been reduced so suddenly.

Many houses have a 100 amp service, and others have a 200 amp service. Theoretically, you could put that same amount back out onto the grid. But check it out: 100 amps at 120 volts equals 12,000 watts. Assuming inverter efficiency of 90%, and assuming you could get 90% of your PV array's rated output, that would mean you would have to have an array of 14,000+ rated watts in order to completely load a 100 amp utility service. At a minimum of US$5 per watt, that would be US$90,000 just for the PV modules. Common inverters are rated at 4 KW, so you would need four of them at about US$2,500 each.

That does not take into account the amount of power your hydroponics may subtract from the amount of power produced. Say your lighting and pumps use 10,000 watts. Do the math—it adds up to a lot of money.

As for the "smart" power system, the only way I can think of to reduce loads in such a system would be to do it manually or with simple timers. Remember, the computer and X-10 equipment are loads in themselves. Michael Welch

Effectiveness of Net Metering Laws
Dear *Home Power,* we recently completed an internship for Redwood Alliance, a nonprofit organization that deals with energy issues. The main focus of our internship was to determine the effectiveness of net metering laws in the 23 states that had these laws at the time of the study. At the end of our project, we felt that our research had raised many important issues and questions for which we have no answers. Yet we feel that these issues are of great relevance to *Home Power* readers and are worth serious consideration.

We began our investigation into the effectiveness of net metering laws in individual states. We wondered: Just how effective are net metering laws? Are they working? Are people satisfied with them? Do states with these laws on the books see a marked increase in users of grid-intertie systems? Are the installers excited about these laws? We made phone calls to any dealer and/or installer that we could get a hold of in each of the 23 states, questioning them as to the main reasons that their customers installed grid interconnected systems and what role net metering laws played in that incentive. We found that the answers were hard to quantify, although most everyone was willing to discuss the situation in great depth and with much passion.

Many of the people we talked to were very frustrated with the way net metering was going in their individual states. One man from New York state was extremely frustrated with the utility in his area because the only way that he could become legally interconnected to the grid was with a certain piece of hardware, which the man was unable to find anywhere. Even the utility didn't know where to get it! We heard many similar stories. Few people had anything positive to say directly about net metering. Many of the responses were along the lines of it not being cost effective, and most of the people interested in RE were interested for

other reasons, such as the independence and being environmentally conscious.

Thus, we have been left wondering if perhaps the real value in net metering is not in the direct benefits to those who are grid interconnected, but indirectly. For example, the process of passing and taking advantage of net metering laws is an educational tool to reach more people with information about renewable energy, especially politicians and utilities.

According to a study by the National Renewable Energy Laboratory, the number of net metering customers in most of the 23 states is less than a dozen households per state. The next logical question is that since net metering directly impacts only a few hundred people nationwide, and most of the benefits associated with it are indirect, are there other means of promoting the use of renewable energy that will reach more people? Now many of you who have fought tooth and nail to get net metering laws enacted in your states may find this question uncomfortable. We believe it bears further examination and discussion. Are our collective energies better spent pushing for net metering laws, or tackling other important issues important to the renewable energy community?

Thus, we pose the questions to you, the readers of *Home Power.* Have we collectively focused our energies on the wrong goal? Is there a better way to get the word out about renewable energy? Are we missing larger issues at hand? Might we be more useful if we concentrated on something with more direct benefits, like favoring RE in deregulation laws? We would like to hear what you—the homeowner, installer/dealer, and potential RE user—think. Chane Binderup • cnb2@axe.humboldt.edu and Sharice Low low@humboldt1.com • Redwood Alliance, PO Box 293, Arcata, CA 95518

Hi Chane and Sharice, Thanks for your good research and for your letter. I hope readers will let you know what they think. As a committed decentralist, I'd caution against moving too far toward a "collective focus." If each of us pursues what we love and what we feel is important, we'll move closer to the goal. Some people think it is important to harass utilities (or they just think it's fun). Other people would rather just quietly put PVs on their roofs. Some people are on fire about renewable energy education. Others like making efficient appliances and lights. Some like selling RE gear. Others like buying it. It takes all kinds to make a world. I'm glad you're asking the questions—we need to regularly evaluate the effectiveness of what we do. I hope we will continue to apply a broader range of solutions to the problems we are concerned about. Ian Woofenden

HP Graphics and Synthetic Oils Spreadsheet

Dear Richard, I received *HP70*—another great issue. The articles are great and the graphics are terrific, really top notch. I wish other magazines would put as much effort into their product. The diagrams on pages 10, 17, and 18 are most impressive (I still have yet to read the full issue). Your graphic designer as well as the person who puts the photos (in color) into the magazine do a most excellent job. I would like to also comment on the advertisers and their ads. They are very well done and help me to more fully grasp the improved technology and products that are now available.

I do design work for an electronics company in Peoria and I try to put as much detail into my drawings as you do. Most of the time I get permitted free rein of what I put into my drawings for the system installers. I have found that if I don't understand how the system works, the installers will probably have trouble installing the system.

In *HP69,* page 50-55, you covered an article about regular oil and synthetic oil. The information was most factual (as are all the articles) and got me to thinking about a way for a person to check for themselves the cost advantages of synthetic over regular oil.

I have put together an Excel spreadsheet that has helped my wife and me compare the cost of both. It takes into account miles driven per year, miles per gallon, cost per gallon of gas, cost of oil and filters, the number of oil changes per year, and the expected (possible) increases in the number of miles per gallon. I thought you would like to see it, and feel free to use it as you would like. Perhaps put a version of it into your magazine or on your Web site. I know it has helped my wife and me compare the costs and make an informed decision.

Keep up the great work. I wish I were as energy independent as you are. I am working toward that end once again, thanks to your excellent magazine and the research I have been able to do over the Internet. Isn't technology great! Thanks again, Loyal Gifford, Washington, IL rabrg@aol.com

Thanks for your appreciation of our diagrams, graphics, and ads. Ben Root is our graphics guru. He designs all the schematic layouts, and lays out the articles. Also, thanks for the oil vs synthetics cost comparison spreadsheet. We will be posting the spreadsheet at www.homepower.com for public download. Michael Welch

Amp Definition

Mr. Woofenden, I have enjoyed *HP* since I found it on the Web and have been reading it cover to cover for the past few months now.

I understand the difficulty of defining electrical terms, and I applaud your effort to do so for your readers. Your column on the amp in *HP69* though, had some slightly ambiguous definitions that I think could have been made clearer.

You said, "An amp is a...rate of current flow." An amp is a unit of current. It is not a unit of "rate of current flow" since "current flow" does not really mean anything and the rate of current flow is even less well defined (it would be a bit like saying that speed is the "rate of velocity motion"—at best misleading, at worst just plain incorrect).

Current is the flow of charge, so "rate of current flow" would mean something like a "rate of rate of charge flow flow" which is not very descriptive. I think that if you took the entire article and replaced "current flow" with "charge flow" you would probably get what you wanted to say.

Just to be a little pedantic: current is measured in charges per unit time, the metric unit of which is the amp as you have stated. Since the metric unit for charge is the coulomb, one ampere is also one coulomb per second. Charges (or if you want to get detailed, "electrons") are the things that flow and their rate of flow is called current and can be measured in amps. Anyhow, keep up the good work. Johann Beda j-beda@pobox.com

Where were you when I needed you, Johann? I really appreciate your feedback and I think you are absolutely correct that my wording was confusing at best. I'm living proof that the best way to learn something is to teach it, and I'm learning a lot! I don't see myself as an "expert," and I think this is an advantage in many ways, since I come at it with fresher eyes. My goal is to help non-technical people understand RE terms and you've caught me failing.

Since I wrote that column, I've done a lot of conferring with others and have come to exactly the same conclusion you did. "Charge flow rate" is the best common language description I've found for what is commonly called "current."

Lots of of electronics textbooks say "flow of current" rather than "flow of charge." Without meaning to, they are reinforcing the misconception that "current" is stuff which can flow. Teachers probably follow the lead of their textbooks and do the same thing, and unwittingly teach their students about "current flow," while perhaps never teaching them about "charge" at all.

Your criticism may seem nit-picky to some, but I think you are right on the money. If we can understand the terms and use them more clearly, it will be easier to understand the concepts. Thanks again for your feedback, and for keeping me honest. Ian Woofenden

CoSEIA Revisited

To the Editor, I just can't let CoSEIA's letter in *HP69* go unanswered. They criticize me for being "misleading" when in fact all I did was quote their very own statistics. Whenever someone resorts to labeling criticism as being "misleading," it means "you got the facts right but we don't agree with your conclusions." They are perfectly welcome not to agree with my conclusions. I do notice, however, that they did not include any specifics on how many rebates were actually in the works or had already been granted.

My major problem with CoSEIA is simply this: for a trade organization to present itself to the powers-that-be in the state of Colorado as representing renewable energy in our state, and to use that as a means to basically monopolize all rebates, does more to harm solar power than to help it. I find it incredibly elitist for CoSEIA to have this rebate monopoly and not insist that it be available to *all* solar installations in the state. The CoSEIA rebate program, *by their own admission,* covers only a fraction of all PV installations in our state, essentially shutting those of us with off-grid and self installed systems out of any hope of getting a rebate. Rebates should be available to any system installed to NEC Code in the state of Colorado, period.

When a trade organization with such obviously self-serving goals gets control of the rebate process, the goal of promoting solar energy loses to the goal of self promotion.

They point out, accurately, that I am not a member of CoSEIA and was "invited to participate" in their program. This is despite the fact that I very clearly stated to them that there was virtually no possibility of any grid-tied installations in my very rural area. If CoSEIA wants to promote urban/suburban grid-tied solar installations, they are more than welcome to. In fact, I encourage them in that goal. But I would hope they would not do it at the expense of the rest of the state.

I also disagree with them that your criticism of John Wiles is misdirected. Their comments about talking to inspectors instead of criticizing John misses the point that John helps to *write* the code while inspectors only interpret and implement it. If you, or anyone, wants to affect changes to the code, the best person to direct comments/criticisms to is John Wiles. Complaining to your local inspectors will just piss them off. See you in Wisconsin, Tom Elliot telliot@wagonmaker.com

Please Help with Utility Intertie in Oklahoma

Mr. Perez: Regards—I have purchased your magazine off the newsstands for years (and should no doubt get a subscription). I am an engineer (petroleum, mechanical, and electrical) and have run my own business for over 20 years. Some time ago, I become involved in distributed power generation. I purchased an entire grid-connected wind farm in the Altamont Pass in California, and successfully took the turbines down and put them in storage. We are now testing a small generating system on the distribution grid of a large utility, and have contracts for many more. This equipment is all utility scale, but I have been interested in (and enlightened by) many of your magazine's articles and letters.

A few months ago, I was asked to join two committees charged with advising the Oklahoma Legislature concerning a wholesale change in utility regulations. These committees are primarily composed of utility company representatives, large companies wanting to market power, and regulators. I may well be the only committee member not on someone's payroll.

Reading your magazine, it is obvious that a number of people are informed and passionate about many of these issues. I would like their voices to be heard—first in Oklahoma, but maybe in other states after that. Specifically, I have taken it upon myself to try to adopt interconnect standards for customer or third party generators installed on the distribution grid. The majority position is that the NEC should govern these tie-ins. I believe the NEC does not come close to adequately covering these issues, and that many of its provisions are (perhaps inadvertently) discriminatory towards small generators.

I would very much like input from engineers, business people, and others with experience in distribution tie-ins, with opinions, suggestions, or comments about interconnect equipment (fuses, breakers, CTs, etc.), about power quality specifications (voltage, frequency, etc.), and other specific technical aspects. I believe we should develop different standards for different sizes and types of generating equipment.

Bear in mind that it is the opinion of regulators that "the other 49 states have adopted the NEC." This means, to me, that if even a single state, such as Oklahoma, can adopt new, better interconnect standards, these might well serve as a model for other states. At the very least, it would help when negotiating with power companies where standards are nonexistent or subject to interpretation.

Lastly, I would ask that all of your interested readers make their opinions known, even if they are not residents of Oklahoma or adjoining states (adjoining states are involved because of utility interconnects). There are constant references in our meetings, largely by utility company engineers and lawyers, to the deregulation experiences of other states. However, the experiences of the consumer and small power producer in these states is not being heard. You can help correct this, and obtain more information by accessing the Web site at www.restructureok.net.

Bear in mind that the proposals and documents you will read have been written by the utility company majority. However, the minority have (and are drafting) minority opinions. Your comments could be most valuable, since there are reasons to believe that the Legislature will adopt many of the minority opinions. Please contact me if you have any suggestions. I appreciate your time, and the input of your readers. David M. Reavis • dmreavis@aol.com

SCAT for Sale, Cheap!
Hi Richard and Staff, is your Phoenix composting toilet up and running? I've been waiting for an update on your bathhouse. Great project!

We are selling plans for a Solar Composting Advanced Toilet (SCAT). The plans are being sold to raise money for the Willapa Water Trail to improve access for paddlers and develop more camp sites around the bay equipped with composting toilets. Check out our Web site. I also recommend reading *The Humanure Handbook: A Guide to Composting Human Manure,* by Joseph Jenkins.

Nasty winter here—glad to have my Air wind genny to supplement the PVs. Take care. Pacifically, Larry Warnberg, Nahcotta, WA • www.solartoilet.com

Hello Larry, yep, our Phoenix composter is up and running. After about 18 months of service, we will soon be harvesting the first load of compost. All has gone relatively well, with a few minor problems. The fan failed after a year and we replaced it. We also had to replace the check valve in the bilge pump. All minor stuff—we are very satisfied with the Phoenix. However, the plans you offer should attract many folks who want to DYI the composting toilet and save some money. Richard Perez

This 'n That
Dear *HP* crew, it's been a while since you've heard from these quarters. No news is usually good news, I suppose. Not much for change here. The system still keeps working and still keeps growing! Presently I'm admiring the increased output from the half dozen new BP75s. On a clear, sunny, winter's day, we kick out about 67 amps at 28 volts. A far cry from the old days with just the dozen Arco 16-2000s.

Had a visit from Dan Alway last fall. He hand delivered our new 24 VDC freezer to us, a fine unit. He's a fascinating person. We had quite a visit, showing him around the ranch. He seemed to think we were probably doin' OK. Of course, everyone who sees the battery room is usually impressed, if only by the magnitude of it. We're up to 8 banks of the 240 NiCd cells, and 2-3 banks of 80s through 160s.

Not too much new in the R&D labs here, no new big projects about to go online. I have been playing off and on with a computer based data gathering system for the last year or two. I want to gather info from shunts throughout the system for currents and voltages. I started with a kit from Electronic Rainbow that allows you to do an analog to digital conversion and input the data via the parallel port on a PC computer. It comes with DOS software that allows you to save up to 8 channels of data in ASCII delimited format, something you can take into Excel.

In the meantime, I came up with a neat computer to hook the thing up to. A scrapper at a computer show had a bunch of 386 laptops for sale, NiCd battery pack and all for the princely sum of $10 each, your pick. Bought 5, 3 for my kids and nephew (they didn't seem to care if they worked or not!) and a couple for me. Got 4 of the 5 working, just simple stuff wrong like unplugged processors.

I thought I'd weigh in on the guerrilla solar issue. Me personally—hey, do what you can get away with. Old bikers aren't known for being particularly pro-establishment. I just hope you won't get in trouble with the magazine for promoting such illegal actions. I would also get concerned about losing your credibility with the more mainstream amongst your readers. I guess I'm thinking if the likes of Jimmy Carter reads this mag, what does this do to their opinion of us independent power makers/users? I'm thinking we're looking for legitimacy here, and your perceived advocacy of theft of services may lose us ears we may need down the road. Well, this is just one guy's opinion. I'm probably getting too conservative in my old age. Keep up the good work with the magazine. I do enjoy the continuing saga of Wrenches vs. Wiles, and Kathleen, too. Sincerely, Dick Linn, Interlaken, NY

Hello Dick, and good to hear from you again. Systems do indeed seem to grow...

On the guerrilla solar issue, I frankly couldn't care less what Jimmy thinks about RE. Or the utilities, or the government, or the megacorportations. RE is technology and it gives us power. How we use it is up to us. Utilities, government, and business is going to have to wake up sometime—there has been a revolution going on here and they've slept through it. Guerrilla solar drives this concept home better than any real world illustration I can imagine. Richard Perez

Fireplace Gizmo
Richard and Karen, first I must say that I read almost every article in *HP* and love it! I really like the new paper too—less eyestrain!

I'm hoping you can help me (and maybe a bunch of your readers). I have been searching for a heat recovery grate made to fit in an existing fireplace. The thing that I've seen somewhere looks like it was made from a series of bent muffler pipes that form a grate. The pipes curve up, over the fire and come out the top front of the fireplace. The idea is that convection heated air is forced through (or blown with a fan) and directs heat back into the room. I really think your readers could use these things, and I do recall seeing them *somewhere.* I've searched the Web to no avail. Can you help? Thanks, Guy Marsden • tekart@well.com

Hello Guy. Glad you like the new paper, we do too and so have all the readers who have commented on it. I've seen ads for that fireplace gizmo, although I don't remember where. I'm sure our readers can help you find it. Have you checked your local stove/fireplace shop? Richard Perez

Solar Cooling
As I enjoy the warmth of the Southwest (actually a little hot today at 90° F), I was wondering if you've done any testing on the DC evaporative coolers I have seen advertised by Sunamp. While my solar-powered home has only a couple of 12 VDC fans, it also has 4 wheels and a motor which carries it to higher/cooler country when it gets too hot, which may be real soon!

Solar-powered evaporative cooling seems ideal for this hot, dry country. I had hoped to see Sunamp at the Southwest Renewable Energy Fair, but didn't see them or their coolers.

I haven't been able to locate *HP70* here; Hastings switched magazine suppliers and *HP* seems to have gotten lost. I wrote to Hastings' president requesting they again carry *HP.* I subscribe, but have it sent to my son in Colorado—like to keep up my reading in the winter. Later, JD Huff, Silt, Colorado

Hello JD. Evaporative coolers will work well in your neighborhood. We've never reviewed any, but there are lots to choose from, both DC and standard 120 VAC. We use a 120 VAC model here—uses about 400 watts at full tilt boogie and about 15 gallons of water daily. Keeps the office cool enough to run computers on even the hottest 100 degree day here. The key is low humidity—swampers work well when the humidity is less than 30%.

We ship HP *to over twenty magazine distributors who in turn send it out to thousands of newsstands worldwide. We have very little control over which specific newsstand gets how many copies. That's up to that specific newsstand's manager. Ask where you normally buy your copies—tell them to stock it and you'll buy it. If you miss out sometimes, then you can always download the current issue for free from our Web site. Richard Perez*

NiCd Batteries
Dear Richard, I wrote to you a very short while ago with a bunch of questions about our NiCd batteries. I have just found out that I am going to get a factory manual on them. Hopefully this will answer all my questions.

Just got *HP69* and it's absolutely terrific. My hat is off—way off—to young Corey Babcock. Now there is a young man that will do good things in this world. My wife and I will make a solar food dryer this summer—if we get any crop that we don't munch on right away, that is!

There are two questions in the back of the mag that perhaps I can assist with. Enclosed is a photocopy of an ad I found. [Ed. note: Keith enclosed an ad for a non-profit organization that has placed small-NiCd recycling bins in stores, including Ace Hardware, Circuit City, Radio Shack, Target, Walmart, Canadian Tire, and Zellers. For a recycling bin near you, contact the Rechargeable Battery Recycling Corp. at 800-822-8837.]

Chris Snyder inquired about earth cooling. Over the years, *Fine Homebuilding* magazine has had any number of ways to cool your home passively, and otherwise. Contact Taunton Press at 800-283-7252 or 203-426-8171. I do recall an article of this nature some time ago, although a quick look through my back issues has not yielded the article. The 55° earth temperature is not just used for cooling, but also to pre-heat the air in the winter when temperatures drop way down. If Chris contacts Taunton I am sure he will find out about many different systems, most of which are a lot simpler than the buried tube idea.

One quick question, our 500 watt wind generator is hooked up directly to the batteries (24 volt). Is there something we can hook up to let us know how much charge we are getting? The E-Meter is bypassed the way it works now. Even with the wind genny running full blast, any load in the system shows up as -X.XX amps on the E-Meter. Do you know if the Windseeker 500 actually puts out a high enough voltage to charge NiCds? Perhaps it would be better if we didn't hook up 20 cells at 1.2 volts each in a row, and tried 19 cells instead. Keith Elliott, Ladysmith, BC, Canada

Hello Keith, the Windseeker will easily put out enough voltage to charge NiCd cells, no need to reduce the pack to 19 series cells. Almost all wind gennys take their rough cue on voltage from the battery (unlike PVs). This means that a few more volts makes no difference. Be sure that any regulator used is set to about 33 VDC or so to accommodate the NiCd cells.

You probably have your E-Meter hooked up incorrectly. The only thing that goes on the negative side of the shunt is the major battery negative. Everything else goes on the other

side of the shunt. Both the Cruising Equipment E-Meter and Bogart Tri-Metric are one channel units, reading net battery amperes. If you want a separate channel that measures RE input (PV, wind, or hydro), then check out the Cruising Equipment Amp-Hours +2 meter. Richard Perez

Money Is Evil?

Greetings Mr. Perez, please allow me to comment on your reply to the nice man from New Zealand who feels guilty for not paying for the electronic edition of *HP*. Your response was, "… our mission is to spread the word about RE, not make money."

This statement and the tone of some *HP* articles suggest a "money is evil" mentality at work. It can be easy to adopt this view when one observes the use of money to influence politicians or build bombs. But is this the fault of money? After spending two entire minutes of creative thinking, I offer the following ideas that additional funds might make possible: 1) subscription "scholarships" for those who don't yet have the means, 2) expand your Adopt a Library program, and 3) translate *HP* for the several billion people who don't speak English.

Money, after all, and like any tool, is neutral. When I convert to the electronic version of *HP* later this year (for environmental, not economic reasons), I will send along my subscription payment. Consider it a contribution to your tool box, an affirmation of what you are doing.

Normally I give out valuable advice such as this for free; today I'll let it go for half price. Tim Delaney, Montrose, CO

Hello, Tim. Thanks for the bargain, and for those of you who truly think money is evil, send all of yours to us immediately. More seriously, you are right-on that money is merely a tool. We don't think money is evil, but it can easily be used as a tool of oppression and abuse.

Here at Home Power, *we need it to get the word out and make sure our staff makes an OK living. When you switch over to the electronic edition (EE), rather than donating the money to us, please find a couple of libraries that would like to have the magazine.*

About your suggestions, one of the reasons we give the EE away for free is for those that are low income. We occasionally get inquiries from students and others for discounts on the hard copy. We just point them to the EE, which is free. Unfortunately, that does not help those who can't afford a computer.

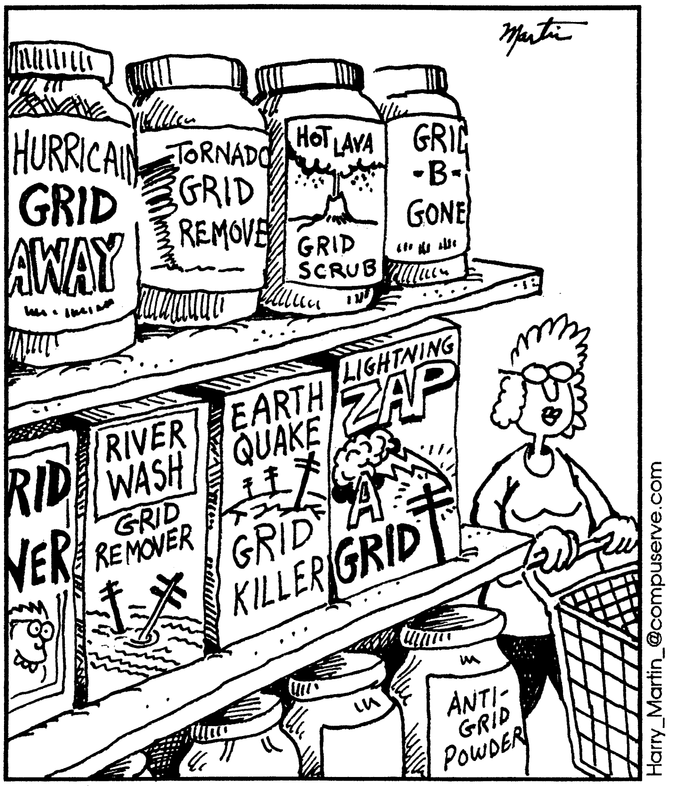
It turns out that the EE has been an acceptable business move for us. It has cut down on the number of sample copies we need to mail, and oftentimes people seeing it for the first time will subscribe to the paper edition. This more than offsets those who give up the paper edition in favor of the free EE. And the advertisers love the fact that tens of thousands of additional copies of their ads are getting out there via the EE.

Expanding the Adopt a Library program is a good idea, and we are for it. How about it, readers—pick a library, check with them, and we will cover half the cost of their subscription.

And finally, translating HP *magazine for non-English speaking populations is something that we've wanted to do for a long time. The problems is that we have only enough time and energy to take care of what we are doing now. Imagine how big a job it would be to oversee a second and third layer of translating, editing, production, and distribution. Phew, the very thought of it wears me out. Michael Welch*

Hello, Tim. I'll answer your suggestions one at a time. Suggestion One: we already give HP *away to anyone who wants it, via our Web pages. Suggestion Two: our Adopt a Library Program is a 50/50 deal—the reader pays half and* HP *pays half. What we need here is for more readers to adopt libraries. Suggestion Three: I've been trying to do this for years. We need skilled publishers in South America, Africa, China, and elsewhere. Our vision is for an independent publication, with advertising from within the local area, and systems which match the local lifestyle. It's not as easy as just translating the words.*

Thanks for all your kind comments. We try hard and your appreciation keeps us trying. Richard Perez



Mother Nature's Anti-Grid Store

Ozonal Notes

Richard Perez

Home Power Grows!
You may have noticed that your copies of *Home Power* are getting heavier. This issue, *HP71,* is our largest issue ever—164 pages! Our industry, the small-scale renewable energy industry, is growing. More folks are installing RE systems and many new companies are springing up to meet the increased demands for RE hardware. After twelve years of publishing *Home Power,* I can now say, “I told you so!” I’ve watched the small-scale RE industry go from diapers to training pants, and now it’s becoming downright “grown up.”

Some folks in the RE industry see the incredible growth during the last year as being driven by Y2K paranoia. I don’t agree. I think folks are installing RE systems for the same reasons they have always installed them—independence, power quality, and environment. And whatever their motives, they get what all of us RE users have come to take for granted—clean, high quality, uninterruptible power. More folks are doing RE because the word is getting around that there is a better way to get your energy than renting it from the power company.

So to all you *Home Power* readers, Karen and I, and the whole *HP* crew want to say thank you! You helped to grow this magazine and the entire small-scale RE industry. When big business said that no one would buy RE gear, you bought it. When energy pundits claimed that no one could live strictly on solar energy, you went totally solar. While the population as a whole continues to use more and more finite resources, you use less, and what you do use is renewable. It’s not big business that grew this industry, but you, the rank and file RE users. Without you there would be no small-scale RE industry and most certainly no *Home Power* magazine. Thank you!

Oregon Net Metering Update
Perhaps I was too pessimistic in last issue’s *Ozonal Notes* regarding Oregon’s net metering bill. In mid April this bill was unanimously passed by the House Commerce Committee with a “Must Pass” recommendation to the whole Oregon House. We have been working with the utilities, PUC, and other energy groups. In spite of this give and take, Oregon’s bill remains essentially uncompromised.

If there are any *HP* readers who are also members of the Sierra Club, you need to talk to the club’s leadership. They are opposing Oregon’s bill because it contains microhydro. We need to bring the Sierra Club up to speed on the environmental impact of microhydro (which is nil). Their knee-jerk reaction is inappropriate and counter to their main purpose. Someone with connections deep in the Sierra Club needs to make them aware of the fact that microhydro has no significant environmental impact. If anyone attempting this needs ammunition, contact me—I’ve got plenty.

While we’ve been busy in the Oregon political trenches, four other states have passed net metering laws—Delaware, Montana, New Jersey, and Virginia. This brings the total to 27 states with net metering laws. Check out *Home Power’s* Web site for a complete and specific update on state net metering legislation.

By the time you read this, Oregon’s net metering bill will have either passed or gone down in flames. Wish us luck and look forward to an article summing up this saga in our next issue.

Utility Worker Safety and Guerrilla Solar
Joe Schwartz’s article on page 58 of this issue should settle the question regarding utility intertie systems and utility worker safety, once and for all. The issue behind guerrilla solar is not safety, but utility control. If utilities will not respond to the people’s demand for interconnection of independent RE systems, then they must face the guerrillas. Let’s be clear on this—people go guerrilla solar because they have no other practical choice. If utilities would allow simple, safe, and fair interconnection with the grid, there would be no reason to go guerrilla. Behind every solar guerrilla, there is a dinosaur of a utility that refuses to change. We all know where that leads—extinction.

Energy Fairs
I don’t know about you, but we at *Home Power* are really looking forward to this summer’s round of energy fairs. The *HP* crew will be attending the tenth annual Midwest Renewable Energy Fair in Amherst, Wisconsin on 19–21 June, the SolWest Renewable Energy Fair in John Day, Oregon on 24–25 July, and the Southwest Renewable Energy Fair in Flagstaff, Arizona on 18–19 September. We hope you all will come to these fairs and join in the fun—we’d love to meet you face to face.

May the sun shine, the wind blow, and the water run free!

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Writing for Home Power Magazine

Home Power is a user's technical journal. We specialize in hands-on, practical information about small scale renewable energy systems. We try to present technical material in an easy to understand and easy to use format. Here are some guidelines for getting your RE experiences printed in Home Power.

Informational Content
Please include all the details! Be specific! We are more interested in specific information than in general information. Write from your direct experience—Home Power is hands-on! Articles must be detailed enough so that our readers can actually use the information.

Article Style and Length
Home Power articles can be between 350 and 5,000 words. Length depends on what you have to say. Say it in as few words as possible. We prefer simple declarative sentences which are short (less than fifteen words) and to the point. We like the generous use of subheadings to organize the information. We highly recommend writing from within an outline. Check out articles printed in Home Power. After you've studied a few, you will get the feeling of our style. System articles must contain a schematic drawing showing all wiring, a load table, and a cost table. Please send a double spaced, typewritten, or printed copy if possible. If not, please print.

Written Release
If you are writing about someone else's system or project, we require a written release from the owner or other principal before we can consider printing the article. This will help us respect the privacy rights of individuals.

Editing
We reserve the right to edit all articles for accuracy, length, content, and basic English. We will try to do the minimum editing possible. You can help by keeping your sentences short and simple. We get over three times more articles submitted than we can print. The most useful, specific, and organized get published first.

Photographs
We can work from any photographic print, slide, or negative. We prefer 4 by 6 inch color prints with no fingerprints or scratches. Do not write on the back of your photographs. Please provide a caption and photo credit for each photo.

Line Art
We can work from your camera-ready art, scan your art into our computers, or redraw your art in our computer. We often redraw art from the author's rough sketches. If you wish to submit a computer file of a schematic or other line art, please call or email us first.

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You can send your article via Internet to richard.perez@homepower.com as an enclosed ASCII TEXT file. If you are sending graphics, or articles with embedded graphics, then use this special email address: rap@snowcrest.net

It is wise to telephone or email ahead of electronic file submission. This is particularly true concerning graphics files. There are many, many, many ducks and they all need to be in a row....

Got any questions? Give us a call Monday through Friday from 9–5 Pacific Time and ask. This saves everyone's time.

Access
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Q&A

Comparing Specs

I've been starting to look into alternative energy recently so that when I move next year I can make a property decision with renewable energy generation in mind. My difficulty is in calculating how much energy I need.

From looking at past energy bills I can see that my maximum usage in any month occurred during summer, when my air conditioning pushed my usage to 840 KWH per month. My average usage is closer to 500 KWH per month.

When I started looking at batteries, wind power, solar power, and inverters, each seems to use a different capacity measurement. Batteries use amp-hours and are DC, solar panels use watts and are DC, inverters show the output in watts as AC, and wind power usually states watts, but fails to state the wind speed that generates that rating and is a mixed bag of variable AC, static AC, and DC.

My question is how these all interact. I'm aware that at 120 VAC, a 100 watt light bulb requires 0.83 amps if my quick calculation is correct. If I run it for an hour, it would use 0.83 amp-hours or 0.1 KWH. However, when translating this to how much battery capacity I need, is it still 0.83 amp-hours, or does the fact that the battery would be at 12 volts mean I need to adjust for that, requiring 8.3 amp-hours of 12 volt battery capacity?

Same question goes for solar panels. Will a 100 watt panel at 12 volts power that 100 watt light bulb, or do I need ten of them? Could you recommend a past article that explains this or a book which uses plain English to describe these conversions? Jeff Morton jmorton@itds.com

Hello Jeff. At least you are starting out looking at the right end of the problem! Renewable energy systems are load driven. Each dollar you spend on efficiency in your loads will save you three to five dollars in system cost. Get catalogs from some of the major suppliers. The good ones have load calculation charts that you can fill out. Also, get yourself a Brand Power Meter and get a handle on what individual loads are adding to your bill.

Your present power consumption is too high for an off-grid home. I have a crowd of kids here and a shop and we generate well under 200 KWH a month. Many RE systems are smaller, though certainly some are larger. First of all, you should realize that it isn't practical to do much of any heating with RE, and air conditioning is a killer load too. Of course, you can do anything you want with RE if your pockets are deep enough, but heating tasks are better done using wood or propane. Some cooling can be done with proper design and with air movement.

Yes, difficulty in comparing different specs is a problem. Try to get everything into watt-hours. This gives you a measure that is universal. A watt-hour is a watt-hour is a watt-hour. You multiply amp-hours by voltage to calculate watt-hours. With PV, you multiply true output watts by hours of full sunlight and you get watt-hours. For other equipment, watts times hours gives you watt-hours.

Wind generator ratings are very deceptive. There is no good standard. Perhaps the best would be KWH generated per month in X average wind speed, but we just don't have those numbers. You have to make a seat-of-the-pants guess. Look carefully at the rated wind speed, the power curves, and your average wind speed. Find someone in the area with a wind generator and compare notes. See HP65 *for Mick Sagrillo's article comparing wind machines.*

Yes, your amp and amp-hour calculations are correct. And at 12 volts, the 100 watt bulb running for an hour is indeed 8.3 amp-hours of battery capacity. You must factor in the voltage to get it right. Taking it all to watt-hours is the easiest way. It would be even easier if all the suppliers would be sensible and rate the gear in watts and watt-hours. A watt is a measure of energy flow—it's a rate. If you have a 100 watt panel, at peak output it will theoretically run a 100 watt light bulb. Voltage is already factored into watts (amps times volts equals watts). Ten 100 W panels would give you one KW. Put them in full sun for one hour and you've generated one KWH.

I don't know of one article or book that pulls all the terminology together, though Ben Root's intro articles in HP52 & 53 *might help you. I've been trying to deal with individual terms in my* Word Power *column, but they are only brief descriptions. I hope this helps.*

Also, if you're shopping for RE property, look for a place with a year-round stream. Microhydro beats PV and wind hands down! The spoiled folks with big streams on their property don't have to worry about efficiency quite as much as the rest of us... Ian Woofenden

Panels Not Putting Out

My system is 24 volts. I have ten MSX-60 Solarex panels hooked up in five pairs. They are combined in a homemade terminal box, wired through a DC breaker box, continuing to my apartment in the house. My problem: I do not get the rated amps that I think I

should get (minimum 17 amps on a sunny day—3.5 amps per pair times five pairs). I get fluctuating amperage, from 11 amps to 20 amps.

For interpanel connection I have used #8 and #10 AWG with forked spade terminals, the kind with the yellow plastic covers that I removed and then crimped and soldered. Initially, I got 17 amps for a few days. Then it went below 15 amps again.

The array is on a Zomeworks tracker. I suspect thermal expansion at this point, making the contacts move. I am concerned about tightening the screw terminals too hard. Did I oversize my interpanel wiring too much so that I have less contact than I should? I did try Solarex's Liquidtight interpanel wiring kit (rain water got into one of them). They use #12 AWG or smaller. I need inspiration from you! R. Rivard, El Prado, NM

Well, R., From your maximum current measurement of 20 it sounds like the PVs are not damaged. Many factors can cause PV current to fluctuate, including module temperature, solar insolation, and battery voltage. The higher the module temperature, the lower the PV current output. The higher the battery voltage, the lower the PV current output. And then there are always wiring problems.

There's nothing wrong with using large gauge wire such as #10 AWG or #8 AWG. I'll bet getting #8 into the junction box was a wrassle. Just be sure to leave slack in the wiring so the wire can expand and contract without mechanically working the connections, and for tracker movement. The spade terminals you used are just fine—large contact area, and you did it up right and soldered the wire to the connector. Your wiring sounds pretty skookum to me.

Try using new star washers on all the spade connector to PV connections. This should help keep them tight even though the PVs and wiring will expand and contract. While you are at this job, measure the short circuit current (should be about 3.8 amperes for each MSX-60 module) by shorting the module into a digital multimeter. This will verify the health of each module and it's easy to do since you have to open up all the connections to insert new star washers anyway.

Be sure to also check all the wiring and connections in the rest of the PV circuit to the battery. It only takes one funky connection to limit the current in the entire circuit. Richard Perez

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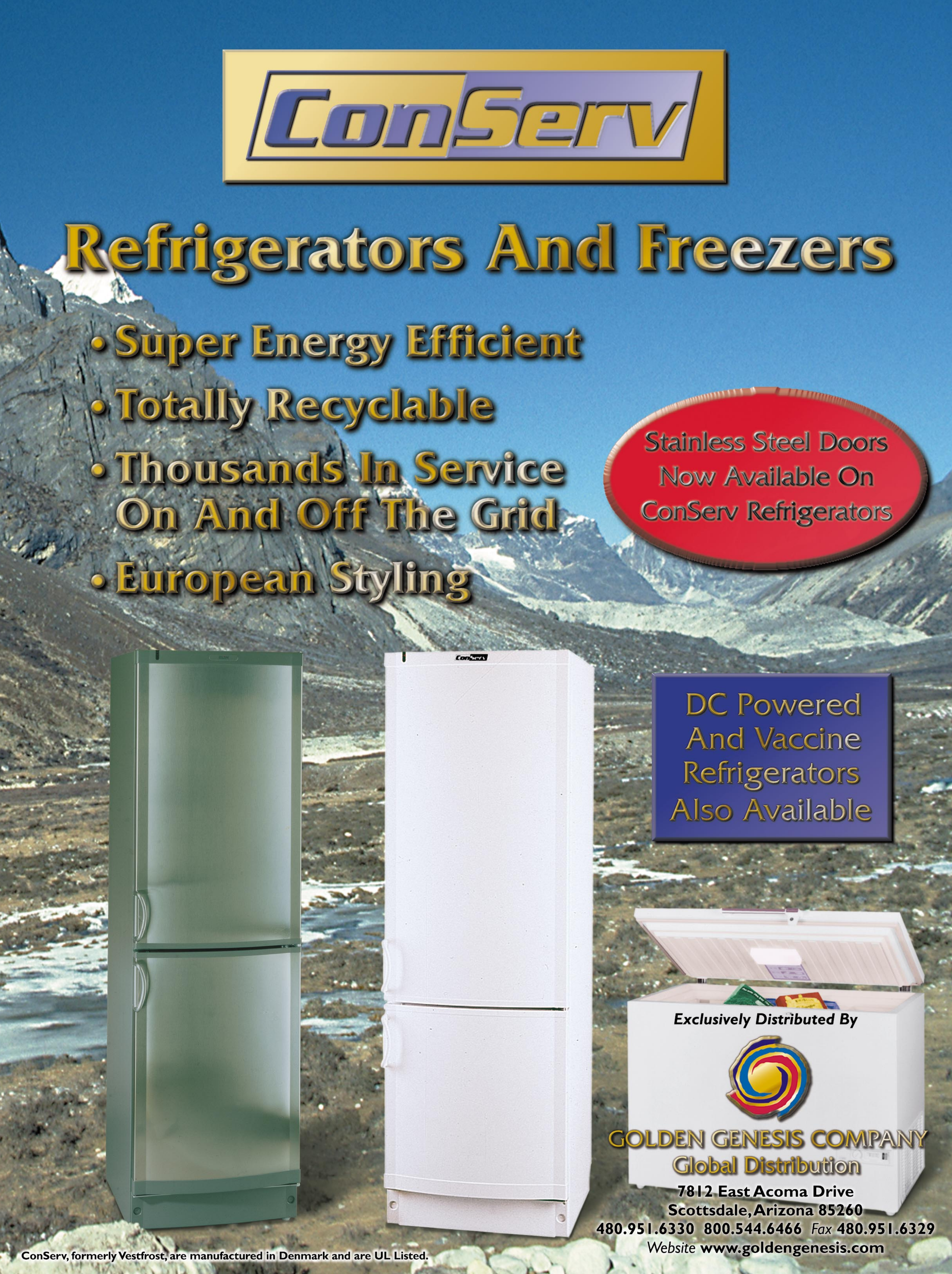
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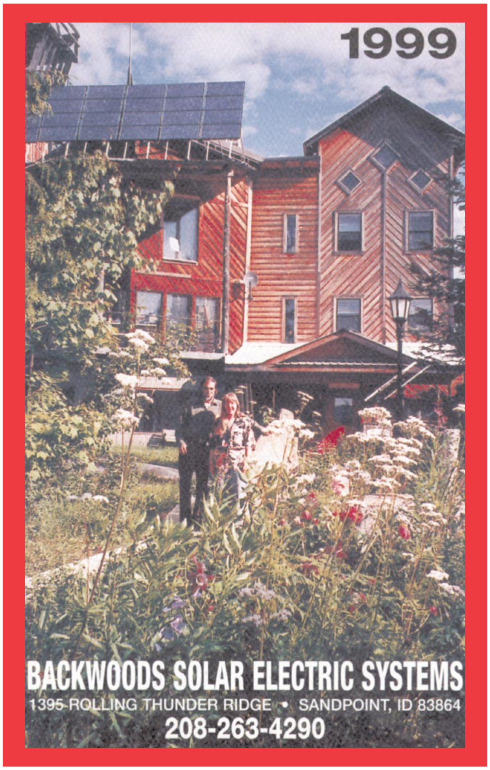

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